Birds and people: Studies based on citizen science and census data of Greater Gauteng, South Africa

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Plagiarism declaration

I know the meaning of plagiarism and declare that all of the work in this thesis, save for that which is properly acknowledged, is my own.

Signature: Signed by candidate

Date: 19th February 2018

Contents

Abstract

Global human population growth has been predicted to grow exponentially, to a point where it exceeds the capacity of available resources to sustain it. The consequences that such exponential increase will have on the environment has also been the focus of several research. The spatial pattern of human population has reveal uneven pattern of human population with the urban areas being subject of increased influx of human population from the rural areas in search of better economic factors. The United Nations in 2007 revealed that at least half of the world's 6.6 billion human population was living in urban areas. This number is expected to increase to over 60% of the world's population by the end of 2050. Most of this population growth is occurring in developing countries. While the health, security and town planning amongst other consequences of this global explosion in urbanization have been well-studied and documented, the impact which urbanization is having and will have on the ecosystem and on biodiversity, especially at regional and local scales has remained an a field of knowledge that has continued to evolve especially given the variable patterns and drivers of urbanization in different regions of the world as well as the different environmental factors and biodiversity in these regions. Biodiversity monitoring has been shown to be crucial to conservation goals aimed at accessing the state and condition of biodiversity. The Second South African Bird Atlas Project (SABAP2) is a citizen science atlas project which commenced in 2007. Over a decade, SABAP2 has produced a rich source of data, capturing bird distributions in South Africa. This makes SABAP2 a powerful tool for monitoring observed changes in bird communities and by extension biodiversity through time.

I examined the effect that urbanization is having on the avian biodiversity in South Africa, one of the most urbanized countries in Africa. My research was focused on the 576 pentads in the four one-degree grid cells (25S 27E, 25S 28E, 26S 27E and 26E 28E) centered on the Gauteng province, referred to as Greater Gauteng region. In addition to being very urbanized, Greater Gauteng is also the most populated area in the country, and is home to 30% of the country's 51 million people. The region is the most atlased SABAP2 region in the country, with each pentad having a minimum of 11 full-protocol SABAP2 checklists. It thus provide opportunities for the development of tools to monitor the temporal dynamics of bird communities.

The first chapter is the general introduction where I did an extensive literature review of the research subject and gave an overview of the data chapters that make up the thesis.

In the second chapter, I examined spatial patterns of urbanization and avian biodiversity. I assess avian species composition in the urban and rural areas of Greater Gauteng. I

categorized bird data from SABAP2 for Greater Gauteng Urban and Rural subgroups. The dataset for this chapter had 700 bird species. 644 showed no range preference for either urban or rural areas. Five species showed a preference for rural areas while 51 species showed a preference for urban areas. The higher species richness recorded in urban pentads highlights the often overlooked benefits of biodiversity conservation efforts in urban areas such as green spaces and parks, gardens and water bodies. This chapter highlights the need for conservation efforts to be targeted at birds and other biodiversity in urban spaces. It is also raises the need to further promote policies aimed at having conservation efforts incorporated into town planning.

In the third and fourth chapters, I used data from SABAP2 to investigate how different protected areas such as Important Bird Areas (IBAs) are to their surrounding areas by demonstrating how different the Devon Grasslands (Chapter 3) and Suikerbosrand Nature Reserve (Chapter 4) IBAs are to their immediate surrounding areas in terms of avian species richness and assemblage. Atlas data from the pentads covering these two IBAs were compared with data from the surrounding pentads. Both IBAs stand out as having more bird species than their immediate surroundings. The simple yet effective method used in this chapters can be applied in identifying potential sites for biodiversity conservation.

In the fifth chapter, using a variation of the Shannon-Weiner species diversity index which is known to reach an asymptote rapidly even while species richness keeps increasing, to investigate patterns of spatial distribution of species richness and proportional diversity in Greater Gauteng. The chapter provides insights into pentads with the richest bird communities and also provides a method which can be applied to citizen science data such as SABAP2 to discover areas where particular groups of species, such as waterbirds and threatened species, are concentrated in the region.

The sixth chapter examines the relationship between reporting rates of birds and human population in Greater Gauteng. With Greater Gauteng being the most populated region in South Africa, it presented an ideal situation to investigate patterns of correlation between human population and the reporting rates of bird species in the region. Based on the results obtained, the species were grouped into 18 groups categorized by the relationship pattern revealed by species reporting rates and human population.

The Seventh chapter follows a similar pattern with chapter six. However, chapter seven, examines patterns between a socio-economic index, mean income per person, and the reporting rates of birds in Greater Gauteng.

The eighth chapter is the conclusion. It gives a synthesis of the thesis and presents the implications for conservation of avian biodiversity in Greater Gauteng.

Overall, this thesis highlights the contribution of citizen science can make to research. It also makes for a strong case showing fundamental importance of large volumes of data such as SABAP2 data, and the useful information that can be harnessed from this data. The conservation-relevant studies in the chapters of this thesis are a result of the spatial distribution patterns of the avifauna revealed by SABAP2 data from Greater Gauteng. It showed how we can detect changes in species abundance, richness and composition in a pentad or in any area, a method we can extend further to detect when bird species are starting to decline or drop out of the species list for a pentad. The results reported in this thesis provides a rich field of study for future research, especially in the field of urban ecology.

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Dedication

To every citizen scientist and SABAP atlaser in Greater Gauteng. This thesis is the fruit of your labour. Where you have toiled and sown, I have reaped. Thank you.

&

Late Angeline Musvuugwa,

(1980 – 2017)

Late Rev. Jantur Wala

(1948 – 2018)

I know you are in a better place

I however, don't know if I will ever get over the pain of your passing away.

Your memories will never be forgotten.

Continue to Rest in Peace

My Sister and Father

Chapter One

Birds and people in urban spaces: Conservation stories from citizen science and census data of Greater Gauteng

Introduction

Global human population currently stands at about 7.2 billion people. The rate of growth in global human population is increasing at an unprecedented rate after witnessing a massive fourfold increase over the last 100 years, due to medical advances, lower mortality rates, and an increase in agricultural productivity. The increase in human population is predicted to continue on an upward trend (United Nations, 2014, Wu, 2014, Esterban and Roser, 2016). The spatial distribution of human population is also said to be unevenly distributed in favour of the urban areas (Vitousek et al., 1997, United Nations, 2010, Wu, 2010, Madlener and Sunak, 2011, Leveau and Leveau, 2012, United Nations, 2014, Wu, 2014, Esterban and Roser, 2016). This exponential increase in human population has presented a number of challenges which are magnified by effects resulting from a disproportional increase in resources needed to support to the growing human population. (Sutton et al., 2001, Grimm et al., 2008, Leveau and Leveau, 2012). It has been projected that, by 2030, more than 60% of the human population will live in urban areas, and that most of this growth will occur in developing nations (UN Population Division, 2001, Paul and Meyer, 2001).

Bird distributions have changed since the 1980s; This is true at all geospatial scales; globally, regionally as well as locally (Bohning-Gaese and Bauer, 1996, Kolecek et al., 2010). The extent to which bird distributions have changed, and the implications this has for bird biodiversity conservation, remains an area of research that is poorly understood, especially as it affects the less developed and tropical regions of Southern hemisphere which includes Africa. In addition, comparatively little research has been done on the effect of growing human population and urbanization on biodiversity in the southern hemisphere, especially in the tropics. This paucity in knowledge driven by little research output on effects of growing human population on biodiversity contributes to the poor understanding of the relationship between growing human population, urbanization and biodiversity (Chuan Lim and Sodhi, 2004, Chase and Walsh, 2006, McKinney, 2008, Leveau and Leveau, 2012). It has become imperative that as urban spaces in Africa continue to expand and encroach into surrounding habitats, more effort needs to be channelled towards understanding the impact which urbanization has on biodiversity in Africa, and it is necessary to find ways to mitigate against the negative impacts and even to harness possible potential opportunities for conservation.

Urbanization is defined as a process which results in temporal and spatial changes in the demographic, economic and environmental aspects of an area (Davis, 1965). Urbanization is characterised by processes which include rapid and often uncontrolled influx of human population from rural areas often motivated by economic factors (Amit and Ambarish, 2014). Biodiversity of an area has also been shown to be affected by these processes of urbanization. The uncontrolled growth in human population around urban centers and the attendant developmental changes that comes with it affects biodiversity in ways which includes; native ecosystems being replaced by pavements and buildings while what is left of the natural soil is covered with green areas often dominated by non-native ornamental species. Wetlands and other peri-urban ecosystems also get destroyed, fragmented or invaded by non-native species which result in a decline or loss of biodiversity (Pauchard et al., 2006, Elmqvist et al., 2016). The loss of native vegetation influences the distribution of bird species, because urban sprawl destroys and fragments native vegetation (McKinney, 2002, Pauchard et al., 2006, McKinney, 2008).

Generally, studies to date have shown that a common result of urbanization is a reduction in species richness (number of species present) and evenness (relative abundance of species present) of most biodiversity (Paul and Meyer, 2001, McKinney, 2008). Many studies have observed that declines in, and extinction of, biodiversity and increasing urbanization are strongly correlated (McKinney, 2002, Thompson et al., 2003, Pauchard et al., 2006, Nature Conservancy, 2008, Ahrne et al., 2009). Urbanization has been shown to have a negative impacts on the diversity of birds and other animals (Czech et al., 2000, Melles et al., 2003) especially species that rely heavily on vegetative complexity (Savard et al., 2000) due to simplification of the ecosystem with increasing impervious surfaces and decreasing vegetative area characteristic of urban development (Blair and Launer, 1997, Marzluff and Ewing, 2001). The same can be said for species endemic to habitats with less complex vegetative structure. For example, diversity of grassland species will also be negatively affected by urbanization when the habitat gets transformed into gardens, parks and other green spaces giving rise to sometimes a more complex vegetative structure than grasslands (Thompson et al. 2003). This transformed vegetative composition is often disproportionately compromised of exotic or alien plant species introduced often for their aesthetic or economic rather than ecological values. This ultimately affects the native species distribution, diversity and abundance as exotic species have been shown to be superior competitors to the native flora and fauna (Rebele F, 1994, Huxel 1999, Ehrenfeld et al., 2001). Urbanization does not always have negative effects on all biodiversity as some research has also shown in situations where biodiversity such as ground arthropods (McIntyre et al., 2000), Plants (McKinney, 2008), birds (Parker, 2013, 2014) as well as some avian and insect pollinators (Baldock et al., 2015) appears to respond positively to some level of increase in urbanization. Furthermore, humans in urban areas mostly in Europe and North America provide resources such as food and nest sites for birds. This action helps maintain biodiversity in the urban areas of these regions.

Justification for this research project

Many studies that have examined the responses of biodiversity to urbanization have focused on developed countries and in temperate regions, even though the impact of urbanization is global (McGranahan and Satterthwaite, 2003, Pauchard et al., 2006). A consequence of this uneven knowledge dynamic is that the conceptual models on the effect of urbanization on biodiversity are derived from temperate regions, and are then often applied to global scenarios. This highlights a knowledge gap in the ecology of urban biodiversity in the tropics and in developing countries despite increasing evidence from studies showing that biodiversity could be affected and respond differently to urbanization in these less studied countries (Lambin et al., 2001, McKinney, 2002, Pauchard et al., 2006). Furthermore, several studies which focused on the effect of urbanization on biodiversity and ecosystem services have projected an expected increase in average of more than three times the size of urban areas near protected areas between 2000 to 2030 (Grimm et al., 2008, Guneralp et al., 2013, McDonald et al., 2013). The largest proportional change is forecast to occur in mid-latitudinal Africa, an area where the relationship between urbanization and biodiversity is poorly understudied and and even less well understood (Guneralp et al., 2013).

Importance of monitoring in biodiversity conservation

Studies on the state of ecosystems, biodiversity loss and extinction rates have indicated that even with no further habitat loss, many species face a high extinction risk, both on global and regional scales (Balmford et al., 2003, Gurevitch and Padilla, 2004, Şekercioğlu et al., 2004, Pereira and Cooper, 2006, Barnosky et al., 2011). The increasing extinction rates faced by biodiversity as captured in previous research forms the core relevance of monitoring programmes in biodiversity conservation efforts. This helps in keeping track of dynamics in population trends and extinction rates of biodiversity. A benefit of proper monitoring programme is identifying the trends in distribution and abundance of species. This gives conservationists the advantage of being able to counteract possible future biodiversity loss by developing relevant policies and targeting conservation plans at species and habitats at higher risk of extinction. It is however, difficult to detect these changes in ecosystems without robust data collected over wide spatial scales as well as over a long period of time (Pereira and Cooper, 2006, Kuussaari et al., 2009).

An example where citizen science has contributed to biodiversity monitoring and conservation can be found in a European multi-country project which investigated breeding Afro-Palearctic migrants (Vickery et al., 2014). The data collected by citizen scientists were synthesized to provide evidence showing a widespread decrease, since the 1980s, of populations of Afro-Palearctic migrant birds breeding in Europe (Sanderson et al., 2006, Thaxter et al., 2010, Vickery et al., 2014). This gives credence to growing conservation concern because the European population of many previously widespread migratory species have more than halved in size within this period. Observed decline in population size of the breeding population of migrants in Europe was made possible through long term data generated by citizen science programmes (Vickery et al., 2014). This also revealed knowledge gaps of the declining species population in the non-breeding part of the life cycle of migrant birds which is often spent in the humid tropics and Guinea forest zones of Africa. This is a potential area that citizen science programmes in Africa such as bird atlas projects can contribute to biodiversity monitoring and conservation. There have been two bird atlas projects in South Africa. The first and second South African Bird Atlas Projects (SABAP1 and SABAP2). SABAP1 is discussed below and SABAP2 which is the main focus of this thesis is a such citizen science driven programme with an initial focus on bird distribution and monitoring projects in South Africa, Lesotho and Swaziland (Harrison and Martinez, 1995, Underhill and Brooks, 2016a, 2016b). SABAP2 now has a presence in east and west Africa (Kung'u and Jackson, 2017, Tende et al., 2017). The conservation implication that data generated by SABAP2 have on birds species and biodiversity, in general, cannot cannot be overemphasized (Underhill et al., 2017).

Data collection is a tedious and expensive process. Generating the type of robust data required for monitoring of biodiversity as explained above requires a massive investment of resources, especially manpower. One of the ways, and perhaps the most efficient way, in which the collection of data has been made possible is through citizen science. Citizen science engages a dispersed network of volunteers to assist in professional research using methodologies that have been developed by, or in combination with, professional researchers (Cooper et al., 2007). This model relies on the public for data collection across broad spatial scales and usually over long periods of time. Citizen science programmes have been shown to make valuable contributions to data collection and analyses which are both critical for meaningful and effective biodiversity monitoring (Schmeller at al., 2009, Loos et al., 2015). This is also true of the Southern African Bird Atlas Project, a leading citizen science programme, which has provided most of the data used for the analyses reported in the subsequent chapters of this thesis. Citizen science continues to be a crucial tool in effective biodiversity monitoring especially in the light of global biodiversity decline in the face of factors such as urbanization, climate change and anthropogenic habitat degradation. This gives rise to the need for a solid evidence base for sound policy and management aimed at biodiversity conservation (Loos et al., 2015).

Citizen science as a vital tool for measuring environmental change impacts on biodiversity

Changes in the environment, such as global change and urbanization, have an impact on biodiversity. Studying these changes requires large volumes of data collected for many species over multiple spatial and temporal scales (Devictor et al., 2010). Citizen science provides a platform for reaching this biodiversity monitoring goal. From this perspective, the redeeming feature of urban areas is that there are citizens who can be motivated to become citizen scientists, given the increased population of people living in urban areas. Citizen science projects, with a carefully designed protocol, can generate vast amounts of data collected over large spatial and temporal scales.

Citizen science is most advanced in developed countries in Europe and North America, where several citizen science programmes targeting different classes of biodiversity as well as spatial scales have been developed and been running for several decades (Silvertown, 2009, Cooper et al., 2014, Loos et al., 2015). Examples of biodiversity projects that have benefitted from citizen science projects includes: Lady beetles in the USA and the UK (Gardiner et al., 2012), Moths in the UK (Bates et al., 2013), Wolves in the US (Miller et al., 2013), Trees in the US (Galloway et al., 2006), Invasive plants in the US (Jordan et al 2012), Bees in the US (Kremen et al., 2011), Butterflies in the UK (Pollard and Yates, 1993) and Romania (Loos et al., 2015), as well as Birds in the US (Sullivan et al., 2009). Citizen science projects have produced outputs from biodiversity and ecosystem monitoring which has given rise to government policies on biodiversity conservation (Devictor et al., 2008, 2010).

Southern African bird atlas projects (SABAP1 and SABAP2)

In South Africa, the Animal Demography Unit (ADU) of the University of Cape Town has been the champion for the development and implementation of citizen science programmes in southern Africa and now they are extending northwards into other countries of the continent, especially Nigeria and Kenya (Tende et al.,2016, Kung'u and Jackson, 2017). The ADU's flagship citizen science project is the Southern African Bird Atlas Project (SABAP). The fieldwork for the first project (SABAP1) was conducted from 1987 to 1991; the major output of SABAP1 was *The Atlas of Southern African Birds*, a two-volume set of books, which provided bird distribution maps for Botswana, Lesotho, Namibia, South Africa, Swaziland and Zimbabwe (Harrison et al., 1997a, b). In 2007, the second SABAP project (SABAP2) was launched and remains ongoing (Harrison et al., 2008, Underhill and Brooks, 2016b). The initial concept of

SABAP2 was to develop a new set of bird distribution maps for South Africa, Lesotho and Swaziland. This concept, however, has shifted over the years since the commencement of SABAP2. The focus now is a project with a long term bird species monitoring role, with the objective of “tracking bird distributions both in time and in space” (Underhill et al., 2017). This is perhaps the first atlas project to take on a long-term monitoring role with tracking temporal and spatial bird distributions as its stated objective (Underhill et al., 2017).

The second Southern African Bird Atlas project (SABAP2) is on course to achieving its new goal of real time monitoring of bird distribution. To date, over 10 million distribution records of birds have been received from 2500 citizen scientists. This is especially true in South Africa, where the project has created the most awareness both in the public and in the conservation authorities. Within South Africa, some regions have more data than others, and this is largely related to human population density. The fieldwork protocol and conceptual background to SABAP2 are focused on a spatial unit called a pentad. A pentad is approximately a rectangular shaped unit measuring five minutes of latitude (c. 9.2 km) by five minutes of longitude (c. 8.2 km). Each pentad has a code name, derived from the coordinates at its north-western corner. An in-depth description of the protocol and the conceptual background to SABAP2 can be found in Harebottle et al. (2007), Loftie-Eaton (2014, 2015), Underhill and Brooks (2014) and Underhill (2016a). Bird lists from each pentad are collected by observers made up mainly of citizen scientists in accordance with the SABAP2 protocol which stipulates lists to be collected within a minimum timeframe of two hours’ intensive fieldwork. A list of observed species within a pentad within this time is called a checklist. Observers do not start a new checklist for the same pentad until five days have elapsed from the time of the last visit. Also, when atlasing, it is encouraged to sample as many of the sub-habitats as possible which occur within the pentad; the objective is to make the checklist as comprehensive as possible (Harebottle et al., 2007, Underhill and Brooks, 2016a).

Aim and Objectives

The overall aim of this research project attempts to bridge the ecology/conservation knowledge gap that exists in the Africa and other developing countries. The general question of this project is: What are the conservation-relevant studies generated from the response of avian biodiversity to pressures from increasing human population and urbanization in Greater Gauteng? The constituent questions are (i) How does urbanization influence the spatial distribution patterns of birds in Greater Gauteng? (ii) What is the ecological function of Important Bird Areas (IBAs) in avian conservation in Greater Gauteng? (iii) How do socioeconomic factors such as the mean household income influence avian species richness and abundance in Greater Gauteng? (iv) How do human population patterns in Greater Gauteng influence the spatial distribution and diversity index patterns of bird species in Greater Gauteng?

Studies have examined the influence of urbanization on biodiversity such as bees, insects and plants (Thompson and Jones, 1999, Thompson et al., 2003, Gaston et al., 2005, Ahrne et al., 2009). These studies found plant diversity to be positively influenced by urbanization in the UK which is explained by gardens and other green spaces in the urban areas (Thompson et al., 2003, Gaston et al., 2005). The diversity and abundance of pollinators such as the bumble bees (*Bombus* spp) were however found to be negatively influenced by urbanization (Ahrne et al., 2009). Most of the South African studies examining the effects of urbanization on biodiversity focused on regions of the country other than Gauteng (Du Plessis, 1995, Richardson et al., 1996, Anderson and Elmqvist, 2012, Pasquini, et al., 2015). This thesis aims to bridge this knowledge gap with information from the results discussed in the chapters. The conservation-relevant studies reported in this thesis will provide insights into how birds are responding to pressures imposed by increasing human population and urbanization in Greater Gauteng region of South Africa.

Data and study area

The bird data used in the research project were downloaded from the SABAP2 database. The SABAP2 provided a valuable data source and presents conservationists with an excellent opportunity for biodiversity monitoring. The study area is referred to as Greater Gauteng (Fig. 1). This is the region with the most

SABAP2 data. The area is covered by 576 pentads all contained within four one-degree grid cell each measuring 15 minutes longitude by 15 minutes latitude. The grid cells are named according to their geolocation as “North west” (25S, 27E), “North east” (25S, 28E), “South west” (26S, 27E) and “South east” (26S, 28E) (Ainsley, 2016). Greater Gauteng region is centred around the Gauteng province, covering parts of North-West, Limpopo, Free State and Mpumalanga provinces (Ainsley, 2016). A more case-relevant and detailed description of the study area is given in the subsequent data chapters of the thesis.

Greater Gauteng has been identified as a rapidly urbanizing region in the country and is home to about 30% of South Africa’s population. These statistics make this the most urban and densely populated four one-degree grid cells anywhere in South Africa, and the area where development and the associated environmental change is predicted to be largest (Statistics South Africa, 2015, Ainsley, 2016). This highlights the need for careful monitoring of biodiversity in the region.

Despite long–term and quality SABAP2 data generated from Greater Gauteng, which makes up the study area for my research, no studies have used this data from to monitor the dynamics of bird abundance, diversity and distribution. Birds as a taxon have been widely used for biodiversity monitoring (Loutte et al., 1995, Gregory et al., 2003, Fernandes et al., 2005, Frederick et al., 2009). The reasons for choosing birds for many studies by ornithologists and some ecological researchers include the relative ease of working with them. Birds are also relatively conspicuous and easily identifiable in the field by citizen scientists thereby making them a feasible taxon to monitor as compared to many other biodiversity taxa such as invertebrates, amphibians and reptiles (Gregory et al., 2005, de Villiers, 2009).

In analysing census and citizen science data from the SABAP2 for Greater Gauteng region, this thesis presents conservation-relevant studies which answer some ecological questions addressing the current state of birds in Greater Gauteng and how increasing human population density, urbanization and socioeconomic factors are impacting on the abundance and distribution patterns of avifauna in the region. The testament to the SABAP2 bird atlas data is attested to by the numbers of papers, many in prestigious journals and theses that have largely made use of SABAP2 data (Underhill, 2016b). These studies are reported in the six data chapters that make up this thesis. The data chapters are preceded by a general introduction chapter that initiates and discusses the general theme and aim that runs through the thesis. A synthesis chapter comes after the data chapters in conclusion of the thesis.

Exploratory data analysis

For data analysis used in this thesis, I employed the well established statistical tradition enshrined in exploratory data analysis as put forward by Tukey (1977, 1980). Exploratory data analysis promotes exploring data for patterns and relationships, the outcome of which fosters the development and refinement in hypothesis testing using confirmatory analysis (Behrens, 1997, Flora and Curran, 2004, Weist et al., 2012). The concept of exploratory data analysis however, do not terminate with the generation and testing of hypothesis. Exploratory data analysis is effective in finding and summarizing patterns in data and thoroughly probing the data and revealing patterns. This approach appears to contrast with the usual scientific method paradigm of stating with a hypothesis based on prior theory, then collecting data, and finally applying a statistical test of the hypothesis. It has been shown that exploratory analyses can incorporate statistical methods of inference, but it uses the statistical methods more as indicators of the strength of a relationship or the fit of a model rather than as confirmation of a hypothesis (Velleman and Hoaglin, 1981, Baumgartner et al., 2000, Flora and Curran, 2004).

Both exploratory and confirmatory data analyses, are essential to scientific research. Finding an answer is not possible without first having a question. Scientific ideas usually come from data explorations, which generate questions and hypothesis which can then be tested by carefully planned confirmatory analysis. An advantage of using exploratory data analysis techniques to explore data is that they often reveal other interesting features not usually described by significance and hypothesis model testing techniques employed by confirmatory data analysis (Tukey, 1980). The techniques employed in exploratory data analysis have been shown to be straightforward and useful. The procedures present an approach that illuminates rather than obscures the analysis of data and makes apparent rather than disguises analytic results (Leinhardt and Leinhardt, 1980, Behrens, 1997). Exploratory data analysis has also been shown to be advantageous when used to analyse spatial data as well as large and long-term data (Anselin, 1999, Perer and Shneiderman, 2008). SABAP2 data is indeed spatial, large and long-term, and therefore is appropriate for the use of exploratory data analysis methods in this thesis.

The objectives of exploratory data analysis include (1) Framing hypotheses about the causes of observed phenomena, (2) Assessing assumptions on which statistical inference will be based, (3) Supporting the selection of appropriate statistical tools and techniques and (4) Providing a basis for further data collection through surveys or experiments (Seltman, 2015). The application of exploratory data analysis to my research is aimed at achieving these objectives.

Structure of the thesis

This first chapter of the thesis provides a general introduction, the aim and objectives of the research and study area for this thesis. It also gives a brief overview of the research questions that make up the subsequent chapters of the thesis.

The second chapter categorized the 576 pentads of Greater Gauteng into urban and rural pentads using the level of urbanization as reflected by the extent of transformation of the landscape from natural habitat/vegetation. Pentads with 75% or more of the landscape transformed were categorized as urban and those with 75% or more of the landscape still natural were categorized as rural. Using data from these pentads I investigated how the observed species richness and abundance are affected by urbanization as reflected in the species distribution patterns in the region.

The third and fourth chapters investigated avian species richness and abundance of two of the Important Bird Areas (IBAs) of Greater Gauteng. I compared the bird species of the Devon grasslands IBA and the Suikerbosrand Nature Reserve IBA with their immediate surrounding landscapes. The Devon grasslands constitute an unprotected IBA while Suikerbosrand Nature Reserve is a fully protected IBA.

Chapter five considers SABAP2 data for species occurring in the 576 pentads of Greater Gauteng and used the data to generate indices of species diversity using an adopted modification of the Shannon-Wiener species diversity index developed by Harrison and Martinez (1995) and further developed by Underhill et al. (1998). I analysed the general bird species diversity and plotted the spatial distribution patterns obtained in Greater Gauteng. I further used the modified equation of the species diversity index to derive the proportional species diversity of different subgroups of avian species such as waterbirds, threatened species and alien species in Greater Gauteng and I plotted the spatial distribution patterns of the proportional diversity of these subgroups in Greater Gauteng. I showed how the methods used in this chapter can be a powerful monitoring tool in biodiversity conservation.

Chapter six examines the relationships between the spatial patterns of avifaunal distribution and the increasing human population in Greater Gauteng. Given that the region is the most densely populated in the country, the data from the 2011 official census of South Africa were used to derive the distribution patterns of the human population by estimating the number of people living in each of the 576 pentads in the region. The chapter investigated the relative abundance of bird species, as provided by the reporting rate, in relation to human populations, on the pentad scale.

Chapter seven has the same theme as Chapter six but investigates the relationship between patterns of relative abundance of birds, and the mean household income of the residents of a pentad. The socio-economic data were also obtained from the 2011 census.

Finally, chapter 8 is a general conclusion to the thesis. It draws on the main conservation related stories arising from Greater Gauteng and reported through the preceding chapters.

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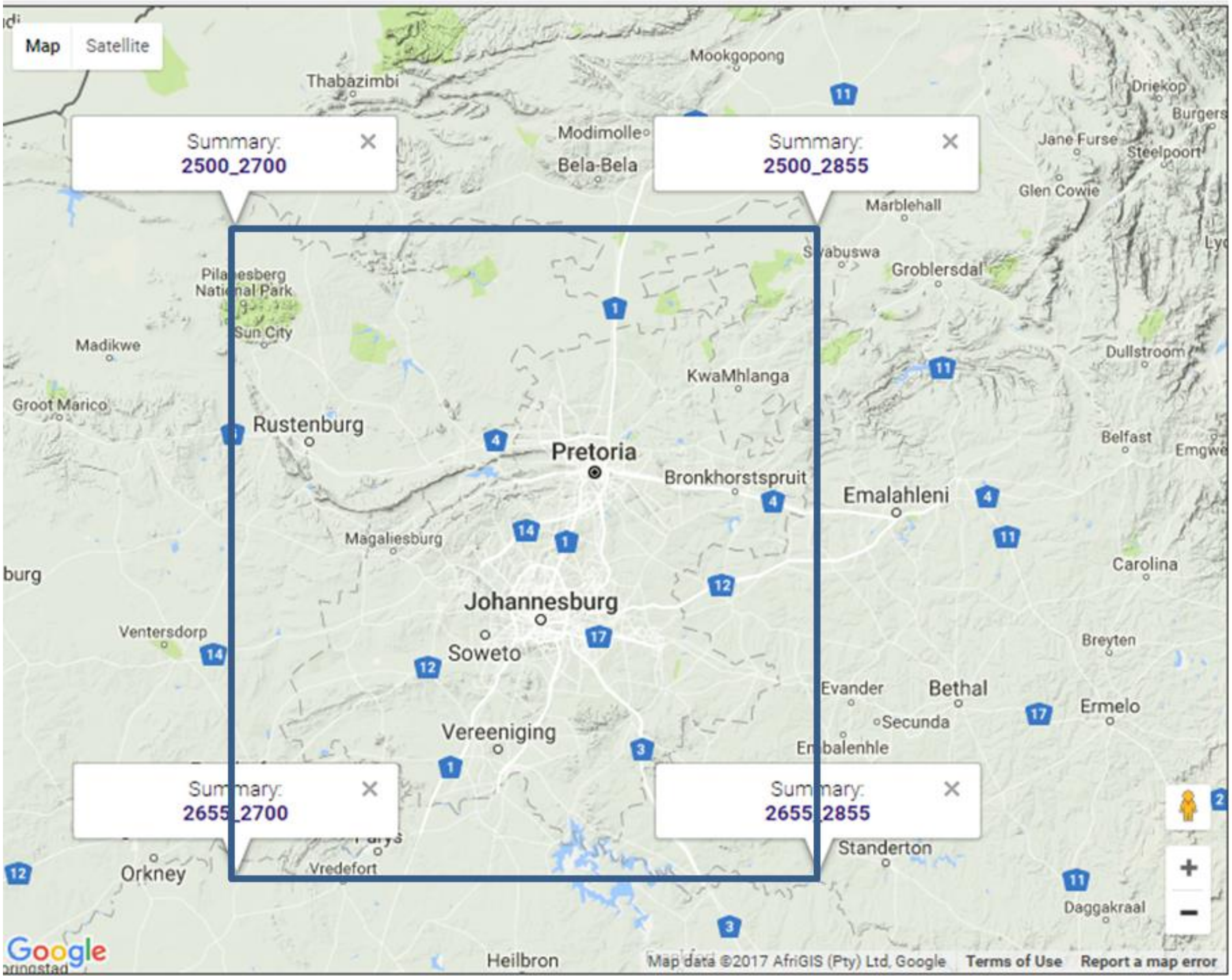

Fig 1: The Outline of Greater Gauteng, South Africa showing provincial boundaries (grey lines). It centers around Gauteng Province; extending to peripheral towns of neighbouring provinces of Limpopo to the north, Mpumalanga to the east, Free State to the south and North-West to the west. The SABAP2 codes for the four pentads at the corners of Greater Gauteng is also shown. (Source: Google Maps)

Chapter Two

How are birds reacting to urbanization in Greater Gauteng?

Abstract

Most studies of urbanization report a simplification of ecosystems through increased impervious surfaces and decreased vegetation complexity, report negative impacts on the distribution and diversity of birds. Most of these studies were focused on the temperate regions of the northern hemisphere. Using bird atlas data generated from 576 SABAP2 pentads in Greater Gauteng, the most urbanized area of South Africa, I studied the effect of urbanization on the avifauna. Using satellite images to quantify the level of development and habitat transformation, 45 of the 576 pentads were categorized as 'Urban' (75% or more of its land use or cover transformed into residential and commercial land-use) and the remaining 531 as 'Rural'. 700 bird species occurred in four or more of the 576 pentads. 51 bird species showed a strong preference for the urban pentads, and five species had a strong preference for the rural pentads. The bird species with a strong preference for the urban areas belonged to seven feeding guilds, compared to two the species preferring rural areas. This distribution of feeding guilds highlights the increased niche complexity offered by the urban areas. The urban birds also had more numbers of birds of regional conservation concern with nine out of the 51 urban species listed as endemic species with one species listed as being Near Threatened, compared to two of 5 rural species listed as endemic and none as being threatened. This research showed that a variety of species are attracted to the urban areas of Greater Gauteng, and that this urban region has the potential to playing a crucial role in the avian conservation.

Introduction

Many studies have observed that biodiversity declines as urbanization increases (McKinney, 2002, Thompson et al., 2003, Pauchard et al., 2006, Nature Conservancy, 2008, Ahrne et al., 2009). However, there is also research which shows that urbanization does not always have a negative effect on biodiversity (McIntyre et al., 2000, McKinney, 2008, Parker, 2013, Parker, 2014, Baldock et al., 2015). In general terms, urbanization promotes homogenization of biota which reduces biodiversity, as measured by species richness. Homogenization of the biota is driven by the process of urbanization which acts as a filter on species traits so that common species in urban areas share biological traits explaining their capacity to tolerate urban constraints (Paul and Meyer, 2001, Angold et al., 2006, Pauchard et al., 2006, Croci et al., 2008, Knapp et al., 2008, McKinney, 2008).

Urbanization has been shown to have negative impacts on the diversity of birds and other animals (Czech et al., 2000, Melles et al., 2003), especially for species which rely heavily on vegetative complexity (Savard et al., 2000, Porzig et al., 2014). This is attributed to simplification of ecosystems with an increase in impervious surfaces and a decrease in vegetated areas, two characteristics of urban development (Blair and Launer, 1997, Marzluff and Ewing, 2001).

Earlier research in the field of urban ecology is focused on temperate regions and developed countries even though the effects of urbanization are felt globally (Thompson and Jones, 1999, Melles et al., 2003, McGranahan and Satterthwaite, 2003, Pauchard et al., 2006, Chace and Walsh, 2006, Grimm et al., 2008, McKinney, 2008, Wu, 2014, Shanahan et al., 2016, Wang Wei et al., 2016). One result of this imbalance in spatial coverage is that most conceptual models on the effects of urbanization on biodiversity and ecosystem services have focused on developed countries. This highlights a knowledge gap in the ecology of urban biodiversity in less developed countries despite evidence showing that biodiversity here could be impacted differently from urbanization in developed and temperate countries (Lambin et al., 2001, McKinney, 2002, Pauchard et al., 2006). There are few studies that have examined the South African context of biodiversity responses to urbanization. These studies however, often focus on other taxa such as bees, insects and plants (Richardson et al., 1996, Anderson and Elmqvist, 2012). Generally, only a few South African studies that examined effect of urbanization on biodiversity have focused on Gauteng region (Du Plessis, 1995, Richardson et al., 1996, Anderson and Elmqvist, 2012, Pasquini et al., 2015). I therefore aim to bridge this knowledge gap in this chapter in the hope that it will provide interesting insights into the response of the avian taxa to the pressures of change in their environment brought about by urbanization in South Africa.

This chapter aims to assess the status of avian biodiversity in the urban area of Greater Gauteng. This area is ideal for this study because it covers the most urban and actively developing areas in South Africa. There is also very rich and readily available avian distribution data of the study area from the SABAP2 database. I hope to be able to find out from this research how urbanization is affecting avian diversity and distribution in Greater Gauteng.

Materials and methods

Study site

Greater Gauteng (Fig. 1.1) consists of four one-degree grid cells centered on the Gauteng province of South Africa (Chapter One). For ease of description, the four grid cells are named by their coordinates and relative positions to each other: 25S 27E (“Northwest”), 25S 28E (“Northeast”), 26S 27E (“Southwest”) and 26S 28E (“Southeast”) (Fig. 1.1). The four grid cells extend beyond Gauteng province, into the neighbouring provinces of Limpopo, North West, Free State and Mpumalanga. The area has 576 SABAP2 pentads (Chapter One); there are 270 pentads which fall entirely within Gauteng province of or have more than 50% of their area within Gauteng province of South Africa. Greater Gauteng is home to about 30% of South Africa's population with Gauteng province alone accounting for 25%. The Greater Gauteng is the most urbanizing part of South Africa and it also holds the largest and the most rapidly increasing human population in South Africa (Ainsley, 2016, Underhill and Brooks, 2016).

Habitat

The study area is covered by two main types of habitat biomes, these are savanna and grassland. The spatial distribution of the two habitat types are split almost evenly along the 26°S latitude; savanna dominates the Northeast and Northwest grid cells north of 26°S and the Southeast and Southwest grid cells, south of 26°S, are dominated by grassland (Allan et al., 1997).

The savanna biome is the largest in southern Africa; it is characterized by a grassy ground layer and an upper layer of woody plants. Savanna is often referred to as woodland. The major environmental delimiting factors of the savanna biome includes altitude and rainfall (Allan et al., 1997). Savannas occur at altitudes ranging from sea level to 2000 m above sea level. The average rainfall in this biome averages 600 mm per year (Low and Rebelo, 1996, Allan et al., 1997).

The grassland biome occurs mainly on the high altitude central plateau of South Africa, and in the inland areas of KwaZulu-Natal and Eastern Cape. The landscape is characterized by rolling flat escarpments. Trees are usually absent in grasslands except for localized stands, mainly in valleys. The vegetation is dominated by a single layer of grasses such as *Themeda triandra, Elionurus muticus, Eragrostis racemosa* and *Tristachya leucothrix* (Mucina et al., 2006) with varying levels of cover dependent on rainfall which averages 450 mm per year. Grasslands occur at altitudes ranging from near sea level to about 2850 m above sea level. In terms of plant species richness, the grassland biome has the second largest number of species in South Africa, with the Fynbos biome in first place (Allan et al., 1997, Marnewick et al., 2015).

Data

Summarized bird lists for each of the 576 pentads within the study area were extracted from the database of the Second Southern African Bird Atlas Project (SABAP2). Chapter 1 contains the relevant details of the project and its fieldwork protocol. The summaries for this chapter consisted of the number of checklists for the pentad, and the number of times each species had been recorded on these checklists. Checklists submitted between July 2007 and August 2016 were used.

Defining data classification (urban vs rural pentads)

Each of the 576 pentads of Greater Gauteng was classified as Urban or Rural by an atlaser (Jerome Ainsley) with personal knowledge of the entire study area, making use of the SABAP2 website (http://sabap2.adu.org.za), which provided satellite images of the study area overlaid by the pentad grid. Pentads which had approximately 75% or more of their area transformed into residential and commercial land-use was categorized as urban. The remainder were classified as rural. The cut off at 75% was chosen because bird species associated with rural and undeveloped areas persist until pentads become transformed to this extent (J. Ainsley pers. comm.)

Statistical Analysis

The number of pentads in which in species was recorded was counted for both the urban and the rural pentads and expressed as a percentage of the total number of pentads that qualified as urban and rural pentads respectively. The difference between these percentages was calculated for each species. The species were sorted on the basis of these differences. Species with positive differences occurred in a comparatively large proportion of the rural pentads than the urban pentads. If the difference was negative, it means the species occurred mainly in urban pentads rather than in rural pentads.

The analysis in this chapter is based firstly on the presence or absence of species in a pentad. A more nuanced approach involves the species reporting rates, which entails the percentage of the checklists submitted for a pentad which reported the species as present. The concept of “reporting rate” used by the bird atlas projects, and its limitations, were discussed by Harrison and Underhill (1997) and Loftie-Eaton

(2014). I computed the median reporting rate for each species by considering only the pentads for which each focal species occurred. The median reporting rates were computed for both the rural and urban pentads. It is worth noting that this is a conditional reporting rate based on the hypothetical question: “given the pentads in which the species occurred, what was the median reporting rate?”. Pentads in which the focal species did not occur were omitted from the calculation for median reporting rates of species.

Because the data were available from every pentad rather than from a sample of pentads of the study area, it forms a census, and therefore formal statistical testing is inappropriate (Underhill, 2016). The approach used here is an example of which falls into “Exploratory Data Analysis”, as championed by Tukey (Tukey, 1977, 1980) and discussed in Chapter One.

Results

Data from all 576 pentads which make up greater Gauteng were analysed. Thirty-two of these pentads were classified as urban pentads while 531 pentads were classified as rural pentads. A total of 700 bird species occurred in four or more of the 576 pentads in the study area (Appendix 1.1). Four bird species (Southern Masked-Weaver *Ploceus velatus*, Red-eyed Dove *Streptopelia semitorquata*, Laughing Dove *Spilopelia senegalensis* and Barn Swallow *Hirundo rustica*) occurred in every one of the 576 pentads. These species therefore have a percentage range difference of zero. A total of 56 bird species had percentage range differences greater than +25% or less than –25% (Tables 2.1 and 2.2). These 56 species were considered to show a strong occurrence range preference for either the rural or urban pentads of Greater Gauteng. Five species Namaqua Dove *Oena capensis*, Red-capped Lark *Calandrella cinerea*, Sabota Lark *Mirafra sabota*, Chestnut-backed Sparrowlark *Eremopterix leucotis* and Kalahari Scrub-Robin *Cercotrichas paena* had positive percentage occurrence range differences greater than 25%. These are species which showed a range preference for rural pentads, hereafter referred to as ‘rural species’ (Table 2.1). At the other end of the scale, 51 bird species had a percentage range smaller than –25%. These are species which show an occurrence range preference for urban pentads in Greater Gauteng, hereafter referred to as ‘urban species’ (Table 2.2).

Species habitat preference

Based on the bird species' habitat, 22 urban species showed partial to major dependence on wetlands and hence they are categorized as wetland species. This comprised 43% of the urban species in Greater Gauteng (Table 2.2). Other microhabitats favoured by the urban species included woodland forest which accounted for 21.6% of urban species, savanna accounting for 11.8%, scrublands and grasslands accounted for 5.0%, riparian and rocky microhabitats accounted for 3.9% while the riverine microhabitat accounted for 2.0% of the urban bird species in Greater Gauteng. For the rural species with greater than 25% percentage range difference, no wetland species was recorded. Two bird species showed a preference for the savanna/shrubland and open woodland habitat while one bird species utilized the arid and semi-arid habitat (Table 2.1).

Migrant species and species of regional conservation concern

The spatial distribution of species of conservation concern as defined by range preference in Greater Gauteng shows the urban areas provide sufficient resources for more species of conservation concern than does rural areas in Greater Gauteng. More bird species of regional conservation concern (Taylor et al., 2015) showed a range preference for the urban areas of the Gauteng (Table 2.3). The urban areas were also preferred by more migrant bird species. The five species that showed a percentage range preference for rural areas were non-migrants while of the 51 bird species that showed a preference for the urban areas of Gauteng, eight were migrant species (five Palearctic and three intra-African migrants). The migrants comprise 15.7% of the urban species (Table 2.3).

Examining the occurrence of alien and invasive species, the results revealed that of the 51 urban species, only one, Mallard *Anas platyrhychos*, is considered an invasive avian species. The mallard occurred in 32 urban pentads scoring an urban percentage range difference of 71%. None of the rural species is however considered to be invasive.

Feeding guild study species

The 56 bird species of Tables 2.1 and 2.2 were classified into 10 feeding guilds. There was a stark difference between the urban and rural avifauna (Table 4.2). The five species which showed a preference for rural areas of Greater Gauteng were from two feeding guilds (three species of granivores and two species of insectivores). On the other hand, however, the 51 species which showed a preference for the urban areas of Greater Gauteng, were from eight feeding guilds. The feeding guild with the most urban bird species was the insectivores which had 15 species (Table 2.4)

Discussion

Previous research has shown various patterns in the abundance and richness of species in urban areas as compared to the rural areas (McKinney, 2008). The most frequently reported trends are an overall pattern of decrease in species richness with increasing urbanization (McKinney and Lockwood, 1999, Chace and Walsh, 2006, McKinney, 2008) and a peak in species richness at intermediate levels of urbanization (Blair 1996, 2004). Few studies have, however, reported an increase in species richness in urban areas (McKinney, 2008). The striking pattern in this study was an increase in species richness in the urban areas of Greater Gauteng when compared to the rural areas (Tables 2.1 and 2.2). Only five bird species (Table 2.2) showed greater percentage range preference in the rural areas of Greater Gauteng, compared with 51 which showed greater percentage preference for the urban areas of Greater Gauteng.

This observed pattern of species richness in Greater Gauteng can be attributed to the reality that transformation from rural to urban in this region converted rural landscapes (grassland and savanna) with few niches into landscapes with multiple and heterogenous niches. Novel habitat was created in Greater Gauteng on a variety of scales. Artificial wetlands were constructed in a dazzling array of forms and sizes, from ornamental garden ponds, through dams and lakes to sewage works, many associated with small and large reed beds, and the planting of trees and shrubs, alien and indigenous species, in parks and gardens has created a huge array of microhabitats (Allan et al., 1997, Marnewick et al., 2015). Such manipulation of the physical environment from its native vegetation structure (savanna in the northern half of Greater Gauteng, and grassland in the southern half) has attracted many bird species to the novel diversity of resources generated within the complex vegetative structures of the urban areas (Pianka and Huey, 1971, Allan et al., 1997). Novel wetland habitat is similarly attractive to many bird species which would not commonly occurred in grassland and savanna (MacArthur and MacArthur, 1961, Allan et al., 1997).

Migrant species and species of regional conservation interest

None of the 56 species of Tables 2.1 and 2.2 were in IUCN threat categories apart from the Half-collared Kingfisher *Alcedo semitorquata* (an urban species) which is classified as Near threatened. Two of the five rural species are endemic to South Africa, Lesotho and Swaziland, while seven of the 51 urban species are either “endemic” or “merit monitoring” (Taylor et al., 2015, appendixes D and F). It is noteworthy, and perhaps counterintuitive, that nine of the species considered by Taylor et al. (2015) to be of future conservation concern have benefitted from the urban areas of Greater Gauteng.

Taylor et al. (2015) noted that many species currently listed as of least regional conservation concern are on a trajectory towards becoming Near Threatened or even Threatened unless deliberate and timely conservation efforts are put in place to counteract current and potential threats faced by regionally endemic and near endemic species (Titeux et al., 2016). The occurrence in Greater Gauteng of avifauna considered endemic to the region presents a potential opportunity to put in place monitoring programmes and conservation action measures which aim to prevent or, at least, control factors that drive loss of species. These factors include the introduction and spread of invasive species, habitat degradation, modification and fragmentation (Pimm et al., 2014). The target of such actions in Greater Gauteng is to help forestall the need for IUCN threat status for these species (Pimm et al., 1995, Brooke et al., 2008).

Feeding guilds

The key result of Table 2.4 is the large variety of feeding guilds represented by the 51 species which showed a preference for the urban areas of Greater Gauteng. This supports the idea of Pianka and Huey (1971) and Allan et al. (1997) that the complex vegetation structure of the urban areas has a greater diversity of microhabitats and niches than the original grassland and savanna habitat. Previous research focused on southern Africa has also recognised vegetation structure as being more critical than plant species composition to most birds (Moreau, 1966, Pianka and Huey 1971, Dean and Hockey, 1989).

The transformation of natural landscape in urban areas such as Greater Gauteng – and many of these transformations are simply aesthetic – resulted in a proliferation of novel ecosystems. These modified habitats and vegetation structures attract bird species which would not be present in grassland or savanna habitats, thereby increasing avian species richness (Elton and Miller, 1954). The basic result of Tables 2.2 and 2.4 were not a surprise; what was unexpected was the fact there were only five species decreased on the rural-urban gradient, and that there were as many as 51 that increased.

The general preference of urban areas by several raptors including Black Sparrowhawk *Accipiter melanoleucus*, Spotted Eagle-Owl *Bubo africanus*, European Honey-Buzzard *Pernis apivorus*, Ovambo Sparrowhawk *Accipiter ovampensis*, African Harrier-Hawk *Polyboroides typus*, Yellow-billed Kite *Milvus aegyptius* and Little sparrowhawk *Accipiter minullus* (Table 2.2), supports previous research in other regions that has found raptors to be adaptable to life in cities by substituting urban alternatives for their traditional prey species (Cringan and Horak, 1989; Chace and Walsh, 2006, Jenkins and Hockey, 2008, Amar et al., 2018). These urban substitutes which are easily accessible to the raptors includes feral pigeons *Columba livia domestica* and other small birds such as the starlings (family Sturnidae) as well as other small prey resources including insects (Cringan and Horak, 1989; Chace and Walsh, 2006). Raptors that eat small prey have been shown to successfully colonize the urban environment (Dietrich and Ellenberg, 1981, Newton, 1986), an observation that raptor distribution in Greater Gauteng supports. The preference for urban areas of Greater Gauteng by selected raptors highlights the role that urban areas of Greater Gauteng play in the conservation of biodiversity considering the position of raptors in the food chain and they ecosystem services they provide (Chiesura, 2004; Chace and Walsh, 2006; Melles, 2005; Parker, 2014, Barth et al., 2015).

Conclusion

Biodiversity conservation in urban areas presents a unique challenge to researchers and conservation scientists given the difference in the drivers of environmental change in the urban areas as compared to the more traditional natural environment. The field of urban ecology is also a relatively new one which is still developing and evolving as the urban environment gets transformed and modified for aesthetic and comfort of humans with little consideration often given to the biodiversity (McKinney, 2002, Chace and Walsh, 2006). More research needs to be carried out with a focus on species found in urban areas, their population trend and adaptation to changes in urban development. It is true that urbanization has a negative impact on biodiversity but as shown here and in other studies, more bird species are increasingly adapting to urban areas thereby highlighting benefits that biodiversity enjoys in urban areas (McKinney, 2002, Chace and Walsh, 2006). Understanding both the impacts and the benefits of urban areas currently and potentially is critical for avian conservation in urban spaces as well as globally (Chace and Walsh, 2006, Pennington et al., 2008).

Research has shown that even severely fragmented patches of habitat amid otherwise transformed or modified landscape can prove to be important for bird diversity (Seymour and Simmons, 2008). The results from this research are in general agreement with this finding; the urban areas of Greater Gauteng provide resources for substantial numbers of bird species. Many species of birds have been shown to respond to vegetation composition and structure in urban areas(Chace and Walsh, 2006). Urban areas which retain native floral characteristics attract more native bird species than areas that have lost most or all its native floral structure (Blair, 2001, Chace and Walsh, 2006).

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Table 2.1: Bird species showing 25% or larger percentage range difference with a preference for rural pentads in Greater Gauteng (see text for detailed column descriptions)

s/no	Common Name	Rural range (No. of Pentads)	Percentage Range	Percentage Range Difference	Feeding guild	Habitat preference
1	Namaqua Dove	430	80.98	36.53	Seedeater	Savanna and shrubland
2	Red-capped Lark	319	60.08	35.63	Seedeater	Open Grassland and Shrubland
3	Sabota Lark	229	43.13	34.24	Insectivores	Savanna and open woodland
4	Chestnut-backed Sparrowlark	169	31.83	29.60	Seedeater	Open grassland and semi arid savanna
5	Kalahari Scrub-Robin	268	50.47	26.03	Insectivorous	Arid and semi-arid

Table 2.2: Bird species showing 25% or larger percentage range difference with a preference for urban pentads in Greater Gauteng

S/No	Common Name	Urban Range (No. of Pentads)	Percentage Range	Percentage Range difference	Feeding guild	Habitat preference
1	Grey-headed Gull	42	93.33	55.86	Opportunistic Feeder	Wetland
2	Mallard Duck	32	71.11	54.16	Omnivore	Wetland
3	Thick-billed Weaver	42	93.33	53.79	Seedeater	Wetland
4	African Purple Swamphen	39	86.67	48.44	Herbivore	Wetland
5	Great Reed-Warbler	33	73.33	48.29	Insectivore	Wetland/Garden
6	Black-crowned Night-Heron	36	80.00	46.29	Insectivore	Wetland
7	Little Rush-Warbler	41	91.11	44.97	Insectivore	Wetland
8	Little Bittern	28	62.22	42.45	Carnivore	Wetland
9	African Reed-Warbler	39	86.67	38.83	Insectivore	Wetland
10	Squacco Heron	38	84.44	38.12	Carnivore	Wetland

S/No	Common Name	Urban Range (No. of Pentads)	Percentage Range	Percentage Range difference	Feeding guild	Habitat preference
11	Fulvous Duck	29	64.44	37.70	Herbivore	Wetland
12	Purple Heron	43	95.56	36.61	Carnivore	Wetland
13	Black Heron	30	66.67	35.40	Carnivore	Wetland
14	Hottentot Teal	25	55.56	34.46	Omnivore	Wetland
15	African Black Duck	40	88.89	34.09	Omnivore	Wetland
16	Orange-breasted Waxbill	34	75.56	33.18	Seedeater	Wetland and Savanna
17	Lesser Swamp-Warbler	45	100.00	32.02	Insectivore	Wetland
18	Green-backed Heron	31	68.89	30.66	Carnivore	Wetland
19	Black Crake	37	82.22	30.62	Omnivore	Wetland
20	Giant Kingfisher	31	68.89	26.52	Carnivore	Wetland
21	White-breasted Cormorant	42	93.33	25.16	Carnivore	Wetland

S/No	Common Name	Urban Range (No. of Pentads)	Percentage Range	Percentage Range difference	Feeding guild	Habitat preference
22	Half-collared Kingfisher	17	37.78	25.16	Carnivore	Wetland
23	African Olive-Pigeon	35	77.78	61.02	Frugivorous	Forest
24	Little Sparrowhawk	29	64.44	44.29	Raptor	Woodland/Forest
25	Marsh Warbler	31	68.89	39.89	Insectivorous	Woodland
26	Yellow-billed Kite	30	66.67	35.97	Raptor	Woodland
27	Red-headed Finch	42	93.33	34.58	Seedeater	Woodland/Forest
28	Ovambo Sparrowhawk	24	53.33	30.73	Raptor	Woodland forest
29	Greater Honeyguide	31	68.89	30.66	Insectivorous	Woodland/Savanna/Grassland/Riverine forest
30	European Honey-Buzzard	21	46.67	30.66	Raptor	Woodland forest
31	Long-crested Eagle	19	42.22	30.17	Raptor	Forest/ moist Woodland

S/No	Common Name	Urban Range (No. of Pentads)	Percentage Range	Percentage Range difference	Feeding guild	Habitat preference
32	Black Sparrowhawk	20	44.44	25.99	Raptor	Forest/Woodland
33	Lesser Honeyguide	33	73.33	25.12	Insectivore	Woodland/Savanna/Riverine forest
34	Bronze Mannikin	32	71.11	37.59	Seedeater	Savanna/Open
35	Horus Swift	28	62.22	37.36	Insectivore	Open/Savanna
36	Grey Go-away-bird	43	95.56	35.67	Herbivore	Savanna woodland
37	Red-throated Wryneck	39	86.67	34.50	Insectivore	Savanna Grasslands
38	Brown-backed Honeybird	24	53.33	31.68	Insectivore	Savanna/Woodland
39	African Harrier-Hawk	23	51.11	31.15	Raptor	Savanna/Woodland/Forest
40	Mountain Wheatear	33	73.33	38.87	Insectivore	Open/Rocky
41	Rock Martin	37	82.22	34.95	Insectivore	Rocky
42	Fairy Flycatcher	25	55.56	32.39	Insectivore	Open Scrublands
43	Common Swift	25	55.56	28.81	Insectivore	Open dry areas

S/No	Common Name	Urban Range (No. of Pentads)	Percentage Range	Percentage Range difference	Feeding guild	Habitat preference
44	Spotted Eagle-Owl	24	53.33	26.59	Raptor	Open Scrublands/Grasslands
45	Rose-ringed Parakeet	25	55.56	53.11	Frugivorous	Riparian
46	Karoo Thrush	43	95.56	27.76	Omnivore	Riparian Woodland/Suburban gardens
47	Peregrine Falcon	15	33.33	25.99	Raptor	Riverine
48	Cape Weaver	33	73.33	33.03	Omnivore	Open Grassland
49	Pied Starling	37	82.22	30.81	Omnivore	Open Grassland
50	Red-winged Starling	36	80.00	36.12	Omnivore	Open
51	Common Peacock	22	48.89	39.10	Omnivore	Dense alien vegetation

Table 2.3: Migrant and regional threat statuses of bird species of Greater Gauteng showing 25% or larger percentage range difference. Species for which a threat status is not shown are classified as Least Concern.

S/No	Common Name	Urban Reporting Rate	Urban Range (No. of pentads)	Percentage Urban Range	Rural Reporting Rate	Rural Range (No. of pentads)	Percentage Rural Range	Percentage Range Difference	Threat Status	Migrant/Resident	Urban/Rural
1	Namaqua Dove	0.652	20	44.44	17.65	430	80.98	36.53		Resident	Rural
2	Red-capped Lark	4.701	11	24.44	20.69	319	60.08	35.63		Resident	Rural
3	Sabota Lark	40.53	4	8.89	20	229	43.13	34.24	Endemic/Near Endemic	Resident	Rural
4	Chestnut-backed Sparrowlark	7.692	1	2.22	9.09	169	31.83	29.60		Resident	Rural
5	Kalahari Scrub-Robin	3.136	11	24.44	26.57	268	50.47	26.03	Endemic/Near Endemic	Resident	Rural
6	African Olive-Pigeon	24.788	35	77.78	5.77	89	16.76	61.02		Resident	Urban
7	Grey-headed Gull	25.143	42	93.33	16.67	199	37.48	55.86		Resident	Urban
8	Mallard Duck	4.978	32	71.11	4.97	90	16.95	54.16		Resident	Urban
9	Thick-billed Weaver	34.237	42	93.33	12.73	210	39.55	53.79		Resident	Urban
10	Rose-ringed Parakeet	9.581	25	55.56	1.92	13	2.45	53.11		Resident	Urban

S/No	Common Name	Urban Reporting Rate	Urban Range (No. of pentads)	Percentage Urban Range	Rural Reporting Rate	Rural Range (No. of pentads)	Percentage Rural Range	Percentage Range Difference	Threat Status	Migrant/Resident	Urban/Rural
11	African Purple Swamphen	7.463	39	86.67	11.76	203	38.23	48.44		Resident	Urban
12	Great Reed-Warbler	1.796	33	73.33	5.26	133	25.05	48.29		Palearctic migrant	Urban
13	Black-crowned Night-Heron	5.474	36	80.00	6.25	179	33.71	46.29		Resident	Urban
14	Little Rush-Warbler	12.892	41	91.11	10.71	245	46.14	44.97		Resident	Urban
15	Little Sparrowhawk	4.545	29	64.44	4.44	107	20.15	44.29		Resident	Urban
16	Little Bittern	2.284	28	62.22	5	105	19.77	42.45		Resident	Urban
17	Marsh Warbler	4.078	31	68.89	5.56	154	29.00	39.89		European Migrant	Urban
18	Common Peacock	2.284	22	48.89	3.23	52	9.79	39.10		Resident	Urban
19	Mountain Wheatear	4.274	33	73.33	9.09	183	34.46	38.87	Endemic/Near Endemic	Resident	Urban
20	African Reed-Warbler	11.111	39	86.67	8.63	254	47.83	38.83		Intra-African Migrant	Urban
21	Squacco Heron	3.337	38	84.44	9.05	246	46.33	38.12		European Migrant***	Urban

S/No	Common Name	Urban Reporting Rate	Urban Range (No. of pentads)	Percentage Urban Range	Rural Reporting Rate	Rural Range (No. of pentads)	Percentage Rural Range	Percentage Range Difference	Threat Status	Migrant/Resident	Urban/Rural
22	Fulvous Duck	3.409	29	64.44	8.17	142	26.74	37.70		Resident	Urban
23	Bronze Mannikin	20.171	32	71.11	8.57	178	33.52	37.59		Resident	Urban
24	Horus Swift	1.213	28	62.22	4.08	132	24.86	37.36		Intra-African Migrant	Urban
25	Purple Heron	7.143	43	95.56	9.35	313	58.95	36.61		Resident	Urban
26	Red-winged Starling	17.039	36	80.00	13.25	233	43.88	36.12		Resident	Urban
27	Yellow-billed Kite	1.815	30	66.67	5.88	163	30.70	35.97		Resident	Urban
28	Grey Go-away-bird	80.392	43	95.56	77.02	318	59.89	35.67		Resident	Urban
29	Black Heron	3.252	30	66.67	7.63	166	31.26	35.40		Resident	Urban
30	Rock Martin	19.608	37	82.22	8.33	251	47.27	34.95		Resident	Urban
31	Red-headed Finch	19.661	42	93.33	13.33	312	58.76	34.58	Endemic/Near Endemic	Resident	Urban
32	Red-throated Wryneck	8.571	39	86.67	12.9	277	52.17	34.50		Resident	Urban
33	Hottentot Teal	5	25	55.56	6.67	112	21.09	34.46		Intra-African Migrant	Urban
34	African Black Duck	17.842	40	88.89	9.68	291	54.80	34.09	Merit Monitoring	Resident	Urban

S/No	Common Name	Urban Reporting Rate	Urban Range (No. of pentads)	Percentage Urban Range	Rural Reporting Rate	Rural Range (No. of pentads)	Percentage Rural Range	Percentage Range Difference	Threat Status	Migrant/Resident	Urban/Rural
35	Orange-breasted Waxbill	4.352	34	75.56	8.33	225	42.37	33.18		Resident	Urban
36	Cape Weaver	4.035	33	73.33	7.69	214	40.30	33.03	Endemic/Near Endemic	Resident	Urban
37	Fairy Flycatcher	2.33	25	55.56	5	123	23.16	32.39	Endemic/Near Endemic	Resident	Urban
38	Lesser Swamp-Warbler	25.49	45	100.00	21.68	361	67.98	32.02		Resident	Urban
39	Brown-backed Honeybird	4.447	24	53.33	4.17	115	21.66	31.68		Resident	Urban
40	African Harrier-Hawk	3.107	23	51.11	3.24	106	19.96	31.15		Resident	Urban
41	Pied Starling	10.454	37	82.22	23.81	273	51.41	30.81	Endemic/Near Endemic	Resident	Urban
42	Ovambo Sparrowhawk	6.36	24	53.33	4.55	120	22.60	30.73	Previously Assessed	Resident	Urban
43	Green-backed Heron	6.549	31	68.89	8.7	203	38.23	30.66		Resident	Urban
44	Greater Honeyguide	3.704	31	68.89	7.14	203	38.23	30.66		Resident	Urban

S/No	Common Name	Urban Reporting Rate	Urban Range (No. of pentads)	Percentage Urban Range	Rural Reporting Rate	Rural Range (No. of pentads)	Percentage Rural Range	Percentage Range Difference	Threat Status	Migrant/Resident	Urban/Rural
45	European Honey-Buzzard	1.287	21	46.67	3.03	85	16.01	30.66		European Migrant	Urban
46	Black Crake	2.596	37	82.22	12.54	274	51.60	30.62		Resident	Urban
47	Long-crested Eagle	1.657	19	42.22	5.56	64	12.05	30.17		Resident	Urban
48	Common Swift	1.059	25	55.56	4.26	142	26.74	28.81		European Migrant	Urban
49	Karoo Thrush	78.289	43	95.56	20	360	67.80	27.76	Endemic/Near Endemic	Endemic	Urban
50	Spotted Eagle-Owl	4.389	24	53.33	5.88	142	26.74	26.59		Resident	Urban
51	Giant Kingfisher	5.831	31	68.89	8.55	225	42.37	26.52		Resident	Urban
52	Black Sparrowhawk	4.469	20	44.44	4	98	18.46	25.99		Resident	Urban
53	Peregrine Falcon	1.441	15	33.33	2.38	39	7.34	25.99		Resident	Urban
54	White-breasted Cormorant	13.157	42	93.33	16.67	362	68.17	25.16		Resident	Urban
55	Half-collared Kingfisher	0.865	17	37.78	3.12	67	12.62	25.16	Near Threatened	Resident	Urban

S/No	Common Name	Urban Reporting Rate	Urban Range (No. of pentads)	Percentage Urban Range	Rural Reporting Rate	Rural Range (No. of pentads)	Percentage Rural Range	Percentage Range Difference	Threat Status	Migrant/Resident	Urban/Rural
56	Lesser Honeyguide	9.926	33	73.33	8.33	256	48.21	25.12		Resident	Urban

Table 2.4: Showing the distribution and occurrence pattern of the different feeding guilds of avian species in Greater Gauteng, South Africa.

Feeding Guild of species	Number of species (Count)		
	Urban Areas	**Rural Areas**	**Total number of species**
Opportunistic Feeder	1	0	1
Seedeater	5	3	8
Insectivore	15	2	17
Omnivore	8	0	8
Herbivore	3	0	3
Carnivore	8	0	8
Frugivore	2	0	2
Raptor	9	0	9

Appendix 1.1: List of bird species from urban and rural pentads of Greater Gauteng

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
1	Namaqua Dove	0.65	20	44.44	17.65	430	80.98	36.53
2	Red-capped Lark	4.70	11	24.44	20.69	319	60.08	35.63
3	Sabota Lark	40.53	4	8.89	20	229	43.13	34.24
4	Chestnut-backed Sparrowlark	7.69	1	2.22	9.09	169	31.83	29.60
5	Kalahari Scrub-Robin	3.14	11	24.44	26.57	268	50.47	26.03
6	Red-billed Oxpecker	33.33	1	2.22	18.18	144	27.12	24.90
7	Southern Yellow-billed Hornbill	41.67	4	8.89	39.02	177	33.33	24.44
8	Black-winged Pratincole	0.42	1	2.22	7.14	141	26.55	24.33
9	White-browed Sparrow-Weaver	2.90	25	55.56	53.57	423	79.66	24.11
10	Blue Waxbill	8.89	19	42.22	56.91	346	65.16	22.94
11	Golden-breasted Bunting	1.96	11	24.44	21.88	247	46.52	22.07
12	Red-breasted Swallow	0.98	16	35.56	21.74	304	57.25	21.69
13	Anteating Chat	3.17	17	37.78	27.78	315	59.32	21.54
14	Long-tailed Paradise-Whydah	0.29	11	24.44	9.09	240	45.20	20.75
15	Brubru	2.31	11	24.44	15.16	239	45.01	20.56
16	Magpie Shrike	1.61	7	15.56	61.02	191	35.97	20.41

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
17	Lilac-breasted Roller	0.82	9	20.00	31.97	212	39.92	19.92
18	Shaft-tailed Whydah	1.16	4	8.89	9.09	153	28.81	19.92
19	Crested Francolin	8.19	12	26.67	33.33	247	46.52	19.85
20	Common Quail	2.51	7	15.56	6.67	187	35.22	19.66
21	Marico Flycatcher	0.45	9	20.00	33.33	209	39.36	19.36
22	Black-chested Snake-Eagle	1.02	14	31.11	7.69	265	49.91	18.79
23	Southern Pied Babbler	12.12	1	2.22	21.43	111	20.90	18.68
24	Black-faced Waxbill	6.06	5	11.11	9.09	154	29.00	17.89
25	Burchell's Starling	45.46	1	2.22	36.36	104	19.59	17.36
26	Greater Kestrel	3.92	13	28.89	8.33	243	45.76	16.87
27	Violet-eared Waxbill	0.54	8	17.78	13.81	184	34.65	16.87
28	Common Ostrich	2.88	17	37.78	13.04	290	54.61	16.84
29	Village Indigobird	1.62	6	13.33	7.79	160	30.13	16.80
30	Lesser Grey Shrike	0.94	20	44.44	9.09	325	61.21	16.76
31	Scaly-feathered Finch	1.61	11	24.44	25	218	41.05	16.61
32	White-backed Mousebird	0.42	9	20.00	11.24	194	36.53	16.53
33	African Red-eyed Bulbul	0.54	12	26.67	25	229	43.13	16.46
34	Kittlitz's Plover	3.70	5	11.11	8.99	146	27.50	16.38

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
35	Red-crested Korhaan	11.74	2	4.44	16.67	110	20.72	16.27
36	Northern Black Korhaan	7.06	26	57.78	33.33	393	74.01	16.23
37	Brown Snake-Eagle	0.21	6	13.33	7.14	157	29.57	16.23
38	Pink-billed Lark	0.29	1	2.22	8.33	97	18.27	16.05
39	Acacia Pied Barbet	3.41	23	51.11	15.59	356	67.04	15.93
40	Spike-heeled Lark	7.46	13	28.89	11.63	237	44.63	15.74
41	White-browed Scrub-Robin	4.37	15	33.33	43.33	257	48.40	15.07
42	Green-winged Pytilia	1.90	15	33.33	14.29	255	48.02	14.69
43	Eastern Clapper Lark	5.26	13	28.89	15.38	229	43.13	14.24
44	Great Spotted Cuckoo	4.58	2	4.44	5.81	99	18.64	14.20
45	Natal Spurfowl	0.94	15	33.33	18.02	252	47.46	14.12
46	Red-billed Hornbill	0.26	5	11.11	27.5	133	25.05	13.94
47	Burnt-necked Eremomela	0.83	7	15.56	17.31	155	29.19	13.63
48	Southern Black Tit	0.58	6	13.33	11.54	143	26.93	13.60
49	Coqui Francolin	2.20	12	26.67	12.5	213	40.11	13.45
50	Ashy Tit	4.85	4	8.89	9.09	118	22.22	13.33
51	Blue Korhaan	0.00	0	0.00	12.7	68	12.81	12.81
52	Purple Roller	3.03	1	2.22	7.69	78	14.69	12.47

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
53	African Fish-Eagle	1.46	17	37.78	9.57	266	50.09	12.32
54	Yellow Canary	2.86	23	51.11	17.65	336	63.28	12.17
55	Brown-crowned Tchagra	8.93	23	51.11	26.25	334	62.90	11.79
56	White-winged Widowbird	4.94	37	82.22	33.33	499	93.97	11.75
57	Emerald-spotted Wood-Dove	0.29	5	11.11	9.09	121	22.79	11.68
58	White-bellied Korhaan	0.00	0	0.00	7.55	62	11.68	11.68
59	Southern White-crowned Shrike	6.06	1	2.22	9.09	71	13.37	11.15
60	Montagu's Harrier	0.00	0	0.00	4.76	59	11.11	11.11
61	Banded Martin	1.43	17	37.78	9.52	259	48.78	11.00
62	Marico Sunbird	1.85	10	22.22	25	176	33.15	10.92
63	Rattling Cisticola	9.21	20	44.44	45.45	293	55.18	10.73
64	Striped Kingfisher	0.24	2	4.44	7.55	80	15.07	10.62
65	African Quailfinch	2.99	35	77.78	25	469	88.32	10.55
66	Long-billed Crombec	10.76	19	42.22	41.67	280	52.73	10.51
67	Bearded Woodpecker	7.20	6	13.33	7.69	125	23.54	10.21
68	Pearl-spotted Owlet	3.69	10	22.22	15	171	32.20	9.98
69	Barred Wren-Warbler	0.21	3	6.67	9.09	88	16.57	9.91
70	Cape Penduline-Tit	6.06	1	2.22	6.67	63	11.86	9.64

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
71	Southern Pale Chanting Goshawk	1.84	2	4.44	8.33	74	13.94	9.49
72	Red-billed Buffalo-Weaver	4.76	2	4.44	16.03	74	13.94	9.49
73	Pearl-breasted Swallow	1.43	17	37.78	13.89	251	47.27	9.49
74	Melodious Lark	1.35	6	13.33	7.69	121	22.79	9.45
75	Grey Tit-Flycatcher	1.61	2	4.44	9.76	72	13.56	9.11
76	Monotonous Lark	0.29	1	2.22	8.33	60	11.30	9.08
77	Bushveld Pipit	3.03	1	2.22	4.55	60	11.30	9.08
78	Grey-backed Camaroptera	0.84	12	26.67	15.38	189	35.59	8.93
79	Violet-backed Starling	2.70	11	24.44	9.09	177	33.33	8.89
80	Secretarybird	0.50	10	22.22	7.37	165	31.07	8.85
81	European Roller	0.42	5	11.11	6.67	106	19.96	8.85
82	Pallid Harrier	0.00	0	0.00	5.26	47	8.85	8.85
83	Red-billed Firefinch	0.65	14	31.11	10	212	39.92	8.81
84	Great Sparrow	0.26	4	8.89	7.17	94	17.70	8.81
85	Chestnut-vented Tit-Babbler	9.04	27	60.00	46.15	365	68.74	8.74
86	Arrow-marked Babbler	26.80	21	46.67	43.42	294	55.37	8.70
87	Double-banded Sandgrouse	0.00	0	0.00	7.2	44	8.29	8.29
88	Rufous-naped Lark	14.82	39	86.67	42.86	504	94.92	8.25

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
89	Comb Duck	0.31	8	17.78	7.14	136	25.61	7.83
90	Cloud Cisticola	9.84	27	60.00	27.27	360	67.80	7.80
91	Fawn-coloured Lark	0.29	1	2.22	4.17	53	9.98	7.76
92	Chinspot Batis	13.40	23	51.11	33.33	311	58.57	7.46
93	African Spoonbill	2.39	29	64.44	13.33	381	71.75	7.31
94	Lark-like Bunting	0.12	1	2.22	2.61	47	8.85	6.63
95	White-crested Helmet-Shrike	0.21	4	8.89	4.17	82	15.44	6.55
96	Wahlberg's Eagle	0.29	6	13.33	8.33	105	19.77	6.44
97	White-throated Robin-Chat	7.84	15	33.33	20	211	39.74	6.40
98	Flappet Lark	15.94	3	6.67	4.17	69	12.99	6.33
99	Crimson-breasted Shrike	5.00	21	46.67	30.45	281	52.92	6.25
100	Yellow-fronted Tinkerbird	2.90	15	33.33	24.4	210	39.55	6.21
101	Dusky Indigobird	0.21	4	8.89	4.12	80	15.07	6.18
102	Red-headed Weaver	0.29	3	6.67	7.85	68	12.81	6.14
103	White-backed Vulture	5.00	1	2.22	2.5	44	8.29	6.06
104	Orange River White-eye	10.11	2	4.44	9.09	55	10.36	5.91
105	Cape Bunting	1.15	7	15.56	6.9	110	20.72	5.16
106	Black Stork	0.13	2	4.44	2.78	51	9.60	5.16

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
107	Osprey	1.32	1	2.22	3.85	39	7.34	5.12
108	Steppe Buzzard	4.16	36	80.00	15.38	450	84.75	4.75
109	Caspian Tern	0.84	3	6.67	8.01	60	11.30	4.63
110	Great Egret	1.27	21	46.67	8.96	272	51.22	4.56
111	Cinnamon-breasted Bunting	5.10	30	66.67	16.67	378	71.19	4.52
112	Cape Vulture	0.30	7	15.56	8.71	106	19.96	4.41
113	Tinkling Cisticola	0.00	0	0.00	2.56	23	4.33	4.33
114	Harlequin Quail	0.32	2	4.44	4.35	46	8.66	4.22
115	Pale-crowned Cisticola	0.00	0	0.00	5.08	22	4.14	4.14
116	Olive-tree Warbler	0.00	0	0.00	6.67	22	4.14	4.14
117	Martial Eagle	2.54	2	4.44	2.27	45	8.47	4.03
118	Red-backed Shrike	1.84	32	71.11	14.84	399	75.14	4.03
119	Bennett's Woodpecker	0.15	2	4.44	5.32	44	8.29	3.84
120	Little Bee-eater	1.96	11	24.44	6.9	149	28.06	3.62
121	Pale Flycatcher	0.29	5	11.11	5.72	78	14.69	3.58
122	Green-capped Eremomela	0.00	0	0.00	6.67	19	3.58	3.58
123	Rock Kestrel	0.53	14	31.11	7.14	184	34.65	3.54
124	Yellow-throated Petronia	0.94	9	20.00	7.69	125	23.54	3.54

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
125	Southern White-faced Scops-Owl	0.15	1	2.22	2.59	30	5.65	3.43
126	Dusky Lark	8.33	1	2.22	3.92	30	5.65	3.43
127	Rufous-cheeked Nightjar	0.29	5	11.11	4.76	77	14.50	3.39
128	Red-footed Falcon	0.23	3	6.67	2.11	53	9.98	3.31
129	Double-banded Courser	0.00	0	0.00	8.33	17	3.20	3.20
130	Temminck's Courser	0.84	9	20.00	5.56	123	23.16	3.16
131	Yellow-throated Sandgrouse	0.00	0	0.00	9.76	16	3.01	3.01
132	Southern Carmine Bee-eater	0.00	0	0.00	6.11	16	3.01	3.01
133	African Marsh-Harrier	5.44	6	13.33	5.56	86	16.20	2.86
134	Grey-backed Sparrowlark	0.00	0	0.00	2.86	15	2.82	2.82
135	Orange River Francolin	5.00	22	48.89	22.25	274	51.60	2.71
136	Green-backed Camaroptera	0.23	1	2.22	2.36	26	4.90	2.67
137	Common Ringed Plover	0.15	3	6.67	5.56	49	9.23	2.56
138	Bronze-winged Courser	0.30	1	2.22	1.99	25	4.71	2.49
139	Desert Cisticola	4.48	30	66.67	11.54	367	69.11	2.45
140	Southern Red-billed Hornbill	0.00	0	0.00	1.28	13	2.45	2.45
141	African Hawk-Eagle	1.70	4	8.89	2.61	60	11.30	2.41
142	Jacobin Cuckoo	0.50	13	28.89	7.69	166	31.26	2.37

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143	Blue Crane	0.45	3	6.67	9.58	48	9.04	2.37
144	Water Thick-knee	0.07	2	4.44	2.9	36	6.78	2.34
145	Blue-cheeked Bee-eater	5.09	2	4.44	8.71	36	6.78	2.34
146	Grey-headed Kingfisher	0.15	1	2.22	3.99	24	4.52	2.30
147	Sickle-winged Chat	0.00	0	0.00	5.21	12	2.26	2.26
148	Namaqua Sandgrouse	0.00	0	0.00	6.62	12	2.26	2.26
149	African Rock Pipit	0.00	0	0.00	2.67	12	2.26	2.26
150	Fork-tailed Drongo	14.86	24	53.33	67.33	294	55.37	2.03
151	Kori Bustard	0.00	0	0.00	6.35	10	1.88	1.88
152	Grey Penduline-Tit	0.00	0	0.00	1.95	10	1.88	1.88
153	Southern Grey-headed Sparrow	27.40	44	97.78	53.33	529	99.62	1.85
154	Yellow-bellied Greenbul	2.64	2	4.44	5.56	33	6.21	1.77
155	Allen's Gallinule	0.00	0	0.00	1.99	9	1.69	1.69
156	African Golden Oriole	0.00	0	0.00	1.92	9	1.69	1.69
157	Swainson's Spurfowl	22.13	44	97.78	57.89	528	99.44	1.66
158	Meyer's Parrot	7.70	2	4.44	9.09	32	6.03	1.58
159	Yellow Wagtail	4.61	1	2.22	3.85	20	3.77	1.54
160	Striped Pipit	5.05	6	13.33	4.55	79	14.88	1.54

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161	Plain-backed Pipit	1.96	15	33.33	6.25	185	34.84	1.51
162	Jameson's Firefinch	4.48	20	44.44	12.5	244	45.95	1.51
163	White-fronted Plover	0.00	0	0.00	1.23	8	1.51	1.51
164	Lappet-faced Vulture	0.00	0	0.00	1.84	8	1.51	1.51
165	Karoo Scrub-Robin	0.00	0	0.00	1.36	8	1.51	1.51
166	Greater Blue-eared Starling	0.00	0	0.00	0.88	8	1.51	1.51
167	Denham's Bustard	0.00	0	0.00	3.57	8	1.51	1.51
168	Ashy Flycatcher	0.00	0	0.00	1.51	8	1.51	1.51
169	Tawny Eagle	0.15	1	2.22	2.17	19	3.58	1.36
170	Terrestrial Brownbul	0.00	0	0.00	8.79	7	1.32	1.32
171	Red-headed Quelea	0.00	0	0.00	0.65	7	1.32	1.32
172	Pink-backed Pelican	0.00	0	0.00	2.94	7	1.32	1.32
173	Shelley's Francolin	2.60	2	4.44	4.38	30	5.65	1.21
174	Swee Waxbill	0.00	0	0.00	2.05	6	1.13	1.13
175	Pririt Batis	0.00	0	0.00	7.14	6	1.13	1.13
176	Pectoral Sandpiper	0.00	0	0.00	3.1	6	1.13	1.13
177	Collared Pratincole	0.00	0	0.00	0.81	6	1.13	1.13
178	African Pygmy-Kingfisher	0.37	3	6.67	2.49	41	7.72	1.05

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179	African Scops-Owl	0.09	2	4.44	3.23	29	5.46	1.02
180	White-throated Bee-eater	1.96	1	2.22	1.67	17	3.20	0.98
181	Red-winged Francolin	0.82	5	11.11	4.45	64	12.05	0.94
182	Thrush Nightingale	0.00	0	0.00	4.4	5	0.94	0.94
183	Square-tailed Nightjar	0.00	0	0.00	0.7	5	0.94	0.94
184	Southern Brown-throated Weaver	0.00	0	0.00	5.88	5	0.94	0.94
185	Ruddy Turnstone	0.00	0	0.00	1.16	5	0.94	0.94
186	Grey Plover	0.00	0	0.00	2.41	5	0.94	0.94
187	Capped Wheatear	9.75	27	60.00	19.78	323	60.83	0.83
188	Southern Tchagra	0.00	0	0.00	1.49	4	0.75	0.75
189	Slaty Egret	0.00	0	0.00	0.41	4	0.75	0.75
190	Scarlet-chested Sunbird	0.00	0	0.00	1.05	4	0.75	0.75
191	Rufous-chested Sparrowhawk	0.00	0	0.00	1.23	4	0.75	0.75
192	Magpie Starling	0.00	0	0.00	1.9	4	0.75	0.75
193	Eurasian Reed-Warbler	0.00	0	0.00	0.43	4	0.75	0.75
194	Common Whimbrel	0.00	0	0.00	1.07	4	0.75	0.75
195	Buff-streaked Chat	0.00	0	0.00	1.29	4	0.75	0.75
196	Broad-tailed Paradise-Whydah	0.00	0	0.00	1.26	4	0.75	0.75

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197	African Skimmer	0.00	0	0.00	3.56	4	0.75	0.75
198	Southern Black Korhaan	0.35	1	2.22	2.27	15	2.82	0.60
199	Yellow-breasted Apalis	0.00	0	0.00	0.74	3	0.56	0.56
200	Whyte's Barbet	0.00	0	0.00	0.4	3	0.56	0.56
201	White-backed Night-Heron	0.00	0	0.00	1.04	3	0.56	0.56
202	Red-faced Cisticola	0.00	0	0.00	1.64	3	0.56	0.56
203	Long-tailed Pipit	0.00	0	0.00	0.59	3	0.56	0.56
204	Lesser Jacana	0.00	0	0.00	2.58	3	0.56	0.56
205	Chestnut-banded Plover	0.00	0	0.00	6.13	3	0.56	0.56
206	Caspian Plover	0.00	0	0.00	8.7	3	0.56	0.56
207	Black-tailed Godwit	0.00	0	0.00	1.5	3	0.56	0.56
208	Bat Hawk	0.00	0	0.00	1.67	3	0.56	0.56
209	African Snipe	7.00	26	57.78	15.79	309	58.19	0.41
210	Black Harrier	0.42	1	2.22	8.41	14	2.64	0.41
211	South African Cliff-Swallow	1.53	30	66.67	21.32	356	67.04	0.38
212	Yellow-breasted Pipit	0.00	0	0.00	1.84	2	0.38	0.38
213	White-browed Coucal	0.00	0	0.00	4.04	2	0.38	0.38
214	Terek Sandpiper	0.00	0	0.00	1.77	2	0.38	0.38

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215	Striped Crake	0.00	0	0.00	0.86	2	0.38	0.38
216	Square-tailed Drongo	0.00	0	0.00	1.19	2	0.38	0.38
217	Short-tailed Pipit	0.00	0	0.00	3.11	2	0.38	0.38
218	Senegal Lapwing	0.00	0	0.00	0.38	2	0.38	0.38
219	Saddle-billed Stork	0.00	0	0.00	5.45	2	0.38	0.38
220	Rufous-eared Warbler	0.00	0	0.00	25	2	0.38	0.38
221	Rufous-bellied Heron	0.00	0	0.00	0.65	2	0.38	0.38
222	Retz's Helmet-Shrike	0.00	0	0.00	2.21	2	0.38	0.38
223	Red-rumped Swallow	0.00	0	0.00	2.01	2	0.38	0.38
224	Orange Ground-Thrush	0.00	0	0.00	2.44	2	0.38	0.38
225	Mountain Pipit	0.00	0	0.00	1.12	2	0.38	0.38
226	Lemon-breasted Canary	0.00	0	0.00	4.49	2	0.38	0.38
227	Karoo Long-billed Lark	0.00	0	0.00	2.3	2	0.38	0.38
228	Ground Woodpecker	0.00	0	0.00	3.32	2	0.38	0.38
229	Grey Cuckooshrike	0.00	0	0.00	0.47	2	0.38	0.38
230	Green-backed Honeybird	0.00	0	0.00	0.26	2	0.38	0.38
231	Gorgeous Bush-Shrike	0.00	0	0.00	1.33	2	0.38	0.38
232	Eurasian Curlew	0.00	0	0.00	3.77	2	0.38	0.38

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233	Dark Chanting Goshawk	0.00	0	0.00	4.98	2	0.38	0.38
234	Croaking Cisticola	0.00	0	0.00	3.03	2	0.38	0.38
235	Common Tern	0.00	0	0.00	3.56	2	0.38	0.38
236	Cinnamon-breasted Warbler	0.00	0	0.00	5.21	2	0.38	0.38
237	Chat Flycatcher	0.00	0	0.00	4.04	2	0.38	0.38
238	Burchell's Sandgrouse	0.00	0	0.00	4.17	2	0.38	0.38
239	Burchell's Courser	0.00	0	0.00	3.3	2	0.38	0.38
240	Black-headed Apalis	0.00	0	0.00	1.66	2	0.38	0.38
241	Black-faced Babbler	0.00	0	0.00	1.56	2	0.38	0.38
242	Bank Cormorant	0.00	0	0.00	0.6	2	0.38	0.38
243	African Penguin	0.00	0	0.00	1.4	2	0.38	0.38
244	African Crowned Eagle	0.00	0	0.00	0.58	2	0.38	0.38
245	Little Stint	10.18	14	31.11	9.09	167	31.45	0.34
246	Short-toed Rock-Thrush	1.96	3	6.67	4.35	37	6.97	0.30
247	Black Cuckoo	6.56	16	35.56	13.77	190	35.78	0.23
248	Yellow-throated Woodland-Warble	0.00	0	0.00	0.35	1	0.19	0.19
249	Yellow-billed Oxpecker	0.00	0	0.00	1.25	1	0.19	0.19
250	Yellow-bellied Waxbill	0.00	0	0.00	0.58	1	0.19	0.19

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251	White-winged Flufftail	0.00	0	0.00	8.33	1	0.19	0.19
252	White-tailed Tropicbird	0.00	0	0.00	1.52	1	0.19	0.19
253	White-headed Vulture	0.00	0	0.00	9.09	1	0.19	0.19
254	Western Violet-backed Sunbird	0.00	0	0.00	2.38	1	0.19	0.19
255	Tropical Boubou	0.00	0	0.00	0.35	1	0.19	0.19
256	Striped Flufftail	0.00	0	0.00	3.45	1	0.19	0.19
257	Streaky-breasted Flufftail	0.00	0	0.00	1.92	1	0.19	0.19
258	Steppe Eagle	0.00	0	0.00	2.56	1	0.19	0.19
259	Stark's Lark	0.00	0	0.00	0.5	1	0.19	0.19
260	Spotted Redshank	0.00	0	0.00	3.12	1	0.19	0.19
261	Spotted Ground-Thrush	0.00	0	0.00	0.2	1	0.19	0.19
262	Sociable Weaver	0.00	0	0.00	1.54	1	0.19	0.19
263	Singing Cisticola	0.00	0	0.00	0.4	1	0.19	0.19
264	Silvery-cheeked Hornbill	0.00	0	0.00	2.17	1	0.19	0.19
265	Short-clawed Lark	0.00	0	0.00	1.59	1	0.19	0.19
266	Senegal Coucal	0.00	0	0.00	6.67	1	0.19	0.19
267	Ruddy Duck	0.00	0	0.00	0.09	1	0.19	0.19
268	Red-necked Phalarope	0.00	0	0.00	1.06	1	0.19	0.19

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269	Red-necked Falcon	0.00	0	0.00	0.63	1	0.19	0.19
270	Red-faced Crombec	0.00	0	0.00	9.09	1	0.19	0.19
271	Red Phalarope	0.00	0	0.00	9.03	1	0.19	0.19
272	Red Lark	0.00	0	0.00	5	1	0.19	0.19
273	Pennant-winged Nightjar	0.00	0	0.00	0.7	1	0.19	0.19
274	Parasitic Jaeger	0.00	0	0.00	1.73	1	0.19	0.19
275	Palm-nut Vulture	0.00	0	0.00	1.09	1	0.19	0.19
276	Pacific Golden Plover	0.00	0	0.00	13.95	1	0.19	0.19
277	Orange-winged Pytilia	0.00	0	0.00	0.46	1	0.19	0.19
278	Mosque Swallow	0.00	0	0.00	0.58	1	0.19	0.19
279	Magpie Mannikin	0.00	0	0.00	5.88	1	0.19	0.19
280	Lesser Sand Plover	0.00	0	0.00	0.32	1	0.19	0.19
281	Lemon Dove	0.00	0	0.00	1.25	1	0.19	0.19
282	Layard's Tit-Babbler	0.00	0	0.00	1.67	1	0.19	0.19
283	Knysna Woodpecker	0.00	0	0.00	0.67	1	0.19	0.19
284	Hottentot Buttonquail	0.00	0	0.00	0.32	1	0.19	0.19
285	Heuglin's Gull	0.00	0	0.00	0.32	1	0.19	0.19
286	Herero Chat	0.00	0	0.00	0.5	1	0.19	0.19

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287	Hartlaub's Spurfowl	0.00	0	0.00	8.33	1	0.19	0.19
288	Hartlaub's Gull	0.00	0	0.00	0.09	1	0.19	0.19
289	Grey-headed Albatross	0.00	0	0.00	1.09	1	0.19	0.19
290	Grey-backed Cisticola	0.00	0	0.00	0.14	1	0.19	0.19
291	Grey Waxbill	0.00	0	0.00	5.88	1	0.19	0.19
292	Grey Kestrel	0.00	0	0.00	9.09	1	0.19	0.19
293	Green Tinkerbird	0.00	0	0.00	2.94	1	0.19	0.19
294	Greater Sand Plover	0.00	0	0.00	1.33	1	0.19	0.19
295	Golden Weaver	0.00	0	0.00	7.14	1	0.19	0.19
296	Eurasian Bittern	0.00	0	0.00	1.96	1	0.19	0.19
297	Common Redstart	0.00	0	0.00	0.74	1	0.19	0.19
298	Chirping Cisticola	0.00	0	0.00	0.09	1	0.19	0.19
299	Chirinda Apalis	0.00	0	0.00	2.22	1	0.19	0.19
300	Cape Rock-jumper	0.00	0	0.00	1.18	1	0.19	0.19
301	Cabanis's Bunting	0.00	0	0.00	0.79	1	0.19	0.19
302	Broad-tailed Warbler	0.00	0	0.00	0.37	1	0.19	0.19
303	Broad-billed Sandpiper	0.00	0	0.00	0.14	1	0.19	0.19
304	Blue-spotted Wood-Dove	0.00	0	0.00	0.55	1	0.19	0.19

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305	Black-throated Wattle-eye	0.00	0	0.00	1.06	1	0.19	0.19
306	Black-bellied Starling	0.00	0	0.00	10	1	0.19	0.19
307	Black-and-white Flycatcher	0.00	0	0.00	8.33	1	0.19	0.19
308	Black Tern	0.00	0	0.00	0.98	1	0.19	0.19
309	Bateleur	0.00	0	0.00	0.74	1	0.19	0.19
310	Atlantic Yellow-nosed Albatross	0.00	0	0.00	0.17	1	0.19	0.19
311	Arnot's Chat	0.00	0	0.00	8.33	1	0.19	0.19
312	Anchieta's Tchagra	0.00	0	0.00	0.59	1	0.19	0.19
313	American Golden Plover	0.00	0	0.00	5.81	1	0.19	0.19
314	African Wood-Owl	0.00	0	0.00	0.98	1	0.19	0.19
315	African Hobby	0.00	0	0.00	2.63	1	0.19	0.19
316	African Emerald Cuckoo	0.00	0	0.00	1.96	1	0.19	0.19
317	Wire-tailed Swallow	0.29	1	2.22	0.68	12	2.26	0.04
318	Brimstone Canary	7.69	1	2.22	1.48	12	2.26	0.04
319	Baillon's Crake	0.42	1	2.22	3.88	12	2.26	0.04
320	Southern Masked-Weaver	94.67	45	100.00	91.67	531	100.00	0.00
321	Red-eyed Dove	88.24	45	100.00	70.73	531	100.00	0.00
322	Laughing Dove	96.30	45	100.00	93.55	531	100.00	0.00

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323	Barn Swallow	36.36	45	100.00	46.09	531	100.00	0.00
324	Common Greenshank	3.29	19	42.22	8.33	224	42.18	-0.04
325	Sentinel Rock-Thrush	3.83	2	4.44	3.45	23	4.33	-0.11
326	Crowned Lapwing	80.00	45	100.00	76.92	530	99.81	-0.19
327	Cape Turtle-Dove	90.91	45	100.00	87.5	530	99.81	-0.19
328	Pin-tailed Whydah	20.47	44	97.78	37.5	518	97.55	-0.23
329	African Finfoot	4.65	2	4.44	2.25	22	4.14	-0.30
330	Verreaux's Eagle-Owl	0.74	1	2.22	2.87	10	1.88	-0.34
331	Grey-winged Francolin	1.43	1	2.22	5.69	10	1.88	-0.34
332	Blacksmith Lapwing	85.08	45	100.00	84.62	529	99.62	-0.38
333	Red-billed Teal	13.29	38	84.44	23.21	446	83.99	-0.45
334	African Cuckoo	0.11	6	13.33	5.26	68	12.81	-0.53
335	Common Myna	95.16	45	100.00	72.73	528	99.44	-0.56
336	Cattle Egret	60.61	45	100.00	67.93	528	99.44	-0.56
337	Black-chested Prinia	21.05	45	100.00	47.34	528	99.44	-0.56
338	Lesser Kestrel	1.20	14	31.11	7.77	162	30.51	-0.60
339	Southern Bald Ibis	2.99	2	4.44	7.18	20	3.77	-0.68
340	Lesser Spotted Eagle	0.41	2	4.44	2.56	20	3.77	-0.68

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341	Red-billed Quelea	9.68	45	100.00	40.62	527	99.25	-0.75
342	Hadeda Ibis	95.15	45	100.00	75	527	99.25	-0.75
343	Black-throated Canary	31.60	45	100.00	53.33	527	99.25	-0.75
344	Cape Eagle-Owl	0.29	1	2.22	0.79	7	1.32	-0.90
345	Helmeted Guineafowl	61.43	45	100.00	69.52	526	99.06	-0.94
346	Diderick Cuckoo	23.68	45	100.00	31.76	526	99.06	-0.94
347	Cape Glossy Starling	68.16	45	100.00	54.55	526	99.06	-0.94
348	Southern Black Flycatcher	1.45	15	33.33	18.18	172	32.39	-0.94
349	African Pipit	20.22	44	97.78	50.54	514	96.80	-0.98
350	Neddicky	25.48	42	93.33	50	490	92.28	-1.05
351	Yellow-rumped Tinkerbird	0.15	1	2.22	1.04	6	1.13	-1.09
352	White-throated Canary	0.23	1	2.22	1.29	6	1.13	-1.09
353	Wattled Crane	0.19	1	2.22	6.86	6	1.13	-1.09
354	American Purple Gallinule	0.15	1	2.22	0.34	6	1.13	-1.09
355	Black-shouldered Kite	42.68	45	100.00	58.82	525	98.87	-1.13
356	Western Marsh-Harrier	0.42	1	2.22	3.33	5	0.94	-1.28
357	Three-banded Courser	0.22	1	2.22	1.02	5	0.94	-1.28
358	Cape Clapper Lark	3.03	1	2.22	0.76	5	0.94	-1.28

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359	Black (Southern race) Saw-wing	0.07	1	2.22	0.21	5	0.94	-1.28
360	Black-crowned Tchagra	6.97	20	44.44	14.29	229	43.13	-1.32
361	Yellow-mantled Widowbird	0.21	1	2.22	0.9	4	0.75	-1.47
362	White-crowned Lapwing	0.12	1	2.22	0.94	4	0.75	-1.47
363	Tree Pipit	9.22	1	2.22	8.01	4	0.75	-1.47
364	Spotted Crake	5.84	1	2.22	1.07	4	0.75	-1.47
365	Great White Pelican	0.29	1	2.22	1.94	4	0.75	-1.47
366	European Turtle-Dove	0.22	1	2.22	0.53	4	0.75	-1.47
367	Cape Batis	0.12	1	2.22	0.65	4	0.75	-1.47
368	Abdim's Stork	0.52	9	20.00	4.83	98	18.46	-1.54
369	Orange-breasted Bush-Shrike	1.79	14	31.11	10.45	157	29.57	-1.54
370	Woolly-necked Stork	3.41	1	2.22	1.47	3	0.56	-1.66
371	White-necked Raven	0.12	1	2.22	1.67	3	0.56	-1.66
372	Violet Wood-Hoopoe	0.10	1	2.22	0.79	3	0.56	-1.66
373	Sanderling	0.43	1	2.22	2.58	3	0.56	-1.66
374	Red-fronted Tinkerbird	0.14	1	2.22	0.74	3	0.56	-1.66
375	Bar-tailed Godwit	0.08	1	2.22	0.6	3	0.56	-1.66
376	Zitting Cisticola	30.00	45	100.00	38.8	522	98.31	-1.69

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377	Speckled Pigeon	63.16	45	100.00	64.38	522	98.31	-1.69
378	Greater Striped Swallow	52.36	45	100.00	43.75	522	98.31	-1.69
379	Yellow-billed Stork	0.65	11	24.44	7.94	120	22.60	-1.85
380	White-tailed Crested Flycatcher	5.00	1	2.22	3.97	2	0.38	-1.85
381	White-eared Barbet	0.07	1	2.22	0.6	2	0.38	-1.85
382	Stierling's Wren-Warbler	5.00	1	2.22	0.96	2	0.38	-1.85
383	Southern Ground-Hornbill	0.29	1	2.22	1.26	2	0.38	-1.85
384	Southern Double-collared Sunbir	0.12	1	2.22	2.38	2	0.38	-1.85
385	Red-billed Spurfowl	0.43	1	2.22	3.56	2	0.38	-1.85
386	Mountain Wagtail	3.30	1	2.22	1.72	2	0.38	-1.85
387	Greater Swamp-Warbler	0.19	1	2.22	0.47	2	0.38	-1.85
388	Bearded Scrub-Robin	5.00	1	2.22	1	2	0.38	-1.85
389	Wood Sandpiper	7.14	25	55.56	9.52	285	53.67	-1.88
390	Cape Sparrow	91.67	45	100.00	73.33	521	98.12	-1.88
391	White-breasted Cuckooshrike	3.11	1	2.22	0.14	1	0.19	-2.03
392	Red-necked Spurfowl	5.00	1	2.22	6.25	1	0.19	-2.03
393	Red-backed Mannikin	0.19	1	2.22	1.25	1	0.19	-2.03
394	Pale-winged Starling	0.10	1	2.22	4.23	1	0.19	-2.03

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395	Miombo Blue-eared Starling	0.10	1	2.22	1.41	1	0.19	-2.03
396	Mangrove Kingfisher	5.00	1	2.22	9.09	1	0.19	-2.03
397	Garganey	0.08	1	2.22	0.41	1	0.19	-2.03
398	Damara Hornbill	0.15	1	2.22	0.35	1	0.19	-2.03
399	Collared Sunbird	0.29	1	2.22	0.98	1	0.19	-2.03
400	Collared Flycatcher	0.29	1	2.22	0.6	1	0.19	-2.03
401	Cape Spurfowl	0.07	1	2.22	3.45	1	0.19	-2.03
402	Cape Long-billed Lark	0.07	1	2.22	7.69	1	0.19	-2.03
403	Blue Swallow	8.33	1	2.22	0.46	1	0.19	-2.03
404	African Yellow White-eye	0.10	1	2.22	1.79	1	0.19	-2.03
405	Amur Falcon	3.29	38	84.44	16.67	437	82.30	-2.15
406	Eurasian Golden Oriole	0.21	3	6.67	4.35	24	4.52	-2.15
407	Woodward's Batis	5.00	1	2.22	0	0	0.00	-2.22
408	Trumpeter Hornbill	10.00	1	2.22	0	0	0.00	-2.22
409	Tiny Greenbul	5.00	1	2.22	0	0	0.00	-2.22
410	Swift Tern	0.25	1	2.22	0	0	0.00	-2.22
411	Southern Banded Snake-Eagle	5.00	1	2.22	0	0	0.00	-2.22
412	Sooty Falcon	0.08	1	2.22	0	0	0.00	-2.22

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413	Sharp-tailed Starling	0.07	1	2.22	0	0	0.00	-2.22
414	Scaly-throated Honeyguide	0.15	1	2.22	0	0	0.00	-2.22
415	Rudd's Apalis	0.10	1	2.22	0	0	0.00	-2.22
416	Red-winged Warbler	5.00	1	2.22	0	0	0.00	-2.22
417	Red-throated Twinspot	5.00	1	2.22	0	0	0.00	-2.22
418	Red-tailed Tropicbird	0.16	1	2.22	0	0	0.00	-2.22
419	Plumheaded Parakeet	0.22	1	2.22	0	0	0.00	-2.22
420	Mottled Spinetail	5.00	1	2.22	0	0	0.00	-2.22
421	Livingstone's Turaco	5.00	1	2.22	0	0	0.00	-2.22
422	Little Blue Heron	1.45	1	2.22	0	0	0.00	-2.22
423	Knysna Turaco	5.00	1	2.22	0	0	0.00	-2.22
424	Karoo Korhaan	0.08	1	2.22	0	0	0.00	-2.22
425	Gull-billed Tern	0.21	1	2.22	0	0	0.00	-2.22
426	Grey-headed Parrot	9.09	1	2.22	0	0	0.00	-2.22
427	Green Twinspot	5.00	1	2.22	0	0	0.00	-2.22
428	Green Malkoha	5.00	1	2.22	0	0	0.00	-2.22
429	Green Barbet	0.12	1	2.22	0	0	0.00	-2.22
430	Franklin's Gull	2.12	1	2.22	0	0	0.00	-2.22

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431	Forest Canary	0.19	1	2.22	0	0	0.00	-2.22
432	European Storm-Petrel	0.19	1	2.22	0	0	0.00	-2.22
433	Eastern Nicator	0.29	1	2.22	0	0	0.00	-2.22
434	Collared Palm-Thrush	0.07	1	2.22	0	0	0.00	-2.22
435	Buff-breasted Sandpiper	0.45	1	2.22	0	0	0.00	-2.22
436	Brown-headed Parrot	0.75	1	2.22	0	0	0.00	-2.22
437	Black-winged Bishop	5.00	1	2.22	0	0	0.00	-2.22
438	Black-eared Seedeater	5.00	1	2.22	0	0	0.00	-2.22
439	Black-cheeked Lovebird	0.21	1	2.22	0	0	0.00	-2.22
440	Yellow-crowned Bishop	12.81	41	91.11	25	472	88.89	-2.22
441	Spectacled Weaver	0.23	2	4.44	0.93	11	2.07	-2.37
442	African Dusky Flycatcher	0.20	2	4.44	1.45	11	2.07	-2.37
443	Greater Painted-snipe	1.80	4	8.89	2.38	34	6.40	-2.49
444	Northern Grey-headed Sparrow	0.20	2	4.44	0.7	10	1.88	-2.56
445	Grey Crowned Crane	1.50	2	4.44	2.28	10	1.88	-2.56
446	White-rumped Swift	39.58	45	100.00	30	517	97.36	-2.64
447	Levaillant's Cuckoo	1.10	14	31.11	7.89	151	28.44	-2.67
448	Lazy Cisticola	1.60	13	28.89	5.26	139	26.18	-2.71

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449	African Openbill	0.21	3	6.67	1.96	21	3.95	-2.71
450	African Grass-Owl	0.42	5	11.11	3.14	44	8.29	-2.82
451	Cape Crow	0.31	8	17.78	9.09	79	14.88	-2.90
452	Curlew Sandpiper	1.20	8	17.78	6.58	78	14.69	-3.09
453	Cape Bulbul	0.15	2	4.44	1.33	7	1.32	-3.13
454	African Pygmy-Goose	0.20	2	4.44	3.87	7	1.32	-3.13
455	Spur-winged Goose	9.09	39	86.67	25	443	83.43	-3.24
456	Wing-snapping Cisticola	1.84	22	48.89	9.09	242	45.57	-3.31
457	African Black Oystercatcher	0.26	2	4.44	0.84	6	1.13	-3.31
458	Icterine Warbler	0.42	8	17.78	3.97	76	14.31	-3.47
459	Sombre Greenbul	2.58	2	4.44	1.05	5	0.94	-3.50
460	Yellow-throated Longclaw	2.54	2	4.44	0.57	4	0.75	-3.69
461	Fiery-necked Nightjar	1.39	10	22.22	6.07	98	18.46	-3.77
462	Crested Barbet	78.27	44	97.78	53.09	499	93.97	-3.80
463	Jackal Buzzard	0.29	9	20.00	4.3	86	16.20	-3.80
464	Yellow-bellied Eremomela	0.85	8	17.78	3.89	74	13.94	-3.84
465	Ruddy Shelduck	1.19	2	4.44	0.33	3	0.56	-3.88
466	Red-capped Robin-Chat	0.19	2	4.44	0.58	3	0.56	-3.88

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467	Grey Wagtail	2.29	2	4.44	0.41	3	0.56	-3.88
468	White-browed Robin-Chat	0.18	4	8.89	2.01	26	4.90	-3.99
469	Lesser Masked-Weaver	0.94	13	28.89	6.67	132	24.86	-4.03
470	Mocking Cliff-Chat	0.62	12	26.67	10.23	120	22.60	-4.07
471	Yellow-collared Lovebird	9.86	2	4.44	3.24	2	0.38	-4.07
472	Cape Cormorant	0.65	2	4.44	0.34	2	0.38	-4.07
473	Broad-billed Roller	0.49	2	4.44	1.25	2	0.38	-4.07
474	Egyptian Goose	77.76	45	100.00	54.55	509	95.86	-4.14
475	Swamp Boubou	0.14	2	4.44	0.63	1	0.19	-4.26
476	House Crow	0.23	2	4.44	1.01	1	0.19	-4.26
477	Grey-rumped Swallow	2.82	2	4.44	0.3	1	0.19	-4.26
478	Common Fiscal	84.21	45	100.00	85.31	508	95.67	-4.33
479	Eastern Long-billed Lark	0.87	7	15.56	4.08	59	11.11	-4.44
480	Tufted Duck	0.17	2	4.44	0	0	0.00	-4.44
481	Thick-billed Cuckoo	0.34	2	4.44	0	0	0.00	-4.44
482	Purple-crested Turaco	2.58	2	4.44	0	0	0.00	-4.44
483	Livingstone's Flycatcher	2.56	2	4.44	0	0	0.00	-4.44
484	Green-backed Woodpecker	2.54	2	4.44	0	0	0.00	-4.44

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485	Drakensberg Prinia	0.10	2	4.44	0	0	0.00	-4.44
486	Crowned Hornbill	0.18	2	4.44	0	0	0.00	-4.44
487	Copper Sunbird	2.58	2	4.44	0	0	0.00	-4.44
488	Groundscraper Thrush	5.97	25	55.56	20.24	271	51.04	-4.52
489	River Warbler	0.70	3	6.67	2.63	11	2.07	-4.60
490	Green Sandpiper	0.21	3	6.67	0.74	11	2.07	-4.60
491	Dwarf Bittern	0.23	4	8.89	1.38	21	3.95	-4.93
492	Buffy Pipit	0.78	16	35.56	5.56	162	30.51	-5.05
493	Dark-capped Yellow Warbler	1.36	4	8.89	3.6	20	3.77	-5.12
494	Common Scimitarbill	0.63	13	28.89	5.68	126	23.73	-5.16
495	Southern Red Bishop	72.41	45	100.00	66.67	503	94.73	-5.27
496	Black-headed Heron	51.74	45	100.00	40	503	94.73	-5.27
497	Corn Crake	1.26	3	6.67	0.6	7	1.32	-5.35
498	Red-crested Pochard	0.45	3	6.67	0.8	6	1.13	-5.54
499	Long-tailed Widowbird	14.19	37	82.22	73.53	407	76.65	-5.57
500	Little Swift	34.18	45	100.00	28.06	501	94.35	-5.65
501	African Barred Owlet	0.15	3	6.67	0.94	5	0.94	-5.73
502	European Bee-eater	21.05	37	82.22	25	406	76.46	-5.76

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503	Alpine Swift	0.42	9	20.00	3.33	75	14.12	-5.88
504	Lesser Black-backed Gull	5.56	3	6.67	12.37	4	0.75	-5.91
505	African Broadbill	3.03	3	6.67	0.58	4	0.75	-5.91
506	Cape Canary	0.21	5	11.11	5.26	27	5.08	-6.03
507	Grey-headed Bush-Shrike	5.88	17	37.78	8.89	168	31.64	-6.14
508	Yellow-fronted Canary	15.74	34	75.56	26.49	368	69.30	-6.25
509	White-fronted Bee-eater	2.83	24	53.33	16.67	250	47.08	-6.25
510	Gabar Goshawk	0.69	18	40.00	7.69	179	33.71	-6.29
511	Chorister Robin-Chat	0.14	3	6.67	1.51	2	0.38	-6.29
512	Bush Blackcap	0.65	3	6.67	2.76	2	0.38	-6.29
513	Shikra	0.52	12	26.67	5.25	108	20.34	-6.33
514	Marabou Stork	1.45	5	11.11	2.13	25	4.71	-6.40
515	Fan-tailed Widowbird	1.45	14	31.11	9.09	131	24.67	-6.44
516	Lesser Moorhen	1.23	6	13.33	1.54	36	6.78	-6.55
517	Tambourine Dove	0.29	3	6.67	0	0	0.00	-6.67
518	Buff-spotted Flufftail	0.36	3	6.67	0	0	0.00	-6.67
519	House Sparrow	59.49	45	100.00	35	495	93.22	-6.78
520	Wattled Starling	5.88	35	77.78	13.71	376	70.81	-6.97

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521	White-faced Duck	15.58	43	95.56	22.65	470	88.51	-7.04
522	Black Cuckooshrike	2.27	15	33.33	8.33	139	26.18	-7.16
523	Lanner Falcon	1.05	16	35.56	6.07	150	28.25	-7.31
524	African Cuckoo Hawk	0.22	6	13.33	2.47	32	6.03	-7.31
525	Cuckoo Finch	0.82	9	20.00	3.46	67	12.62	-7.38
526	Purple Indigobird	1.22	12	26.67	5.71	102	19.21	-7.46
527	African Mourning Dove	0.17	4	8.89	1.05	7	1.32	-7.57
528	African Goshawk	0.17	4	8.89	2.38	7	1.32	-7.57
529	Yellow Bishop	0.43	7	15.56	3.08	42	7.91	-7.65
530	Greater Double-collared Sunbird	0.75	7	15.56	4.79	42	7.91	-7.65
531	South African Shelduck	1.06	20	44.44	8.7	195	36.72	-7.72
532	Black-headed Canary	0.22	4	8.89	1.74	6	1.13	-7.76
533	Cape Rock-Thrush	2.13	8	17.78	5.56	53	9.98	-7.80
534	Common Whitethroat	0.79	7	15.56	5.26	41	7.72	-7.83
535	Cut-throat Finch	5.83	14	31.11	7.14	123	23.16	-7.95
536	White-winged Tern	3.99	18	40.00	8.96	170	32.02	-7.98
537	Black-necked Grebe	1.35	8	17.78	6.07	52	9.79	-7.98
538	Crested Guineafowl	0.32	6	13.33	1.64	27	5.08	-8.25

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539	Ruff	8.19	20	44.44	10	192	36.16	-8.29
540	Whiskered Tern	6.96	28	62.22	14.42	286	53.86	-8.36
541	Klaas's Cuckoo	4.59	18	40.00	7.69	167	31.45	-8.55
542	Southern Boubou	47.34	30	66.67	36.09	308	58.00	-8.66
543	Common Waxbill	10.68	45	100.00	23.63	485	91.34	-8.66
544	European Nightjar	0.29	5	11.11	0.85	13	2.45	-8.66
545	Ayres's Hawk-Eagle	2.22	4	8.89	2.86	1	0.19	-8.70
546	Freckled Nightjar	1.44	7	15.56	4.76	36	6.78	-8.78
547	Green Wood-Hoopoe	44.26	41	91.11	21.43	437	82.30	-8.81
548	Familiar Chat	1.85	24	53.33	10	236	44.44	-8.89
549	White-backed Duck	7.41	15	33.33	7.69	129	24.29	-9.04
550	Reed Cormorant	47.92	45	100.00	50	483	90.96	-9.04
551	Common Cuckoo	0.29	5	11.11	0.63	10	1.88	-9.23
552	Long-billed Pipit	1.43	17	37.78	6.67	151	28.44	-9.34
553	African Grey Hornbill	16.67	27	60.00	40	269	50.66	-9.34
554	Little Grebe	26.67	45	100.00	33.33	480	90.40	-9.60
555	Golden-tailed Woodpecker	8.33	23	51.11	12.13	220	41.43	-9.68
556	Hamerkop Hamerkop	5.49	36	80.00	11.76	373	70.24	-9.76

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557	Malachite Sunbird	0.58	10	22.22	6.25	66	12.43	-9.79
558	Black-collared Barbet	57.79	44	97.78	36.36	467	87.95	-9.83
559	Black-winged Stilt	15.60	28	62.22	14.29	278	52.35	-9.87
560	African Crake	0.43	7	15.56	1.64	30	5.65	-9.91
561	Lizard Buzzard	0.41	8	17.78	6.42	41	7.72	-10.06
562	Levaillant's Cisticola	34.84	43	95.56	53.33	454	85.50	-10.06
563	Red-faced Mousebird	60.00	45	100.00	48.39	477	89.83	-10.17
564	Cape Wagtail	60.00	45	100.00	47.62	477	89.83	-10.17
565	Yellow-billed Duck	33.33	45	100.00	50	475	89.45	-10.55
566	Dark-capped Bulbul	92.47	45	100.00	66.67	475	89.45	-10.55
567	Brown-hooded Kingfisher	11.75	29	64.44	27.27	285	53.67	-10.77
568	African Stonechat	40.69	44	97.78	72.73	462	87.01	-10.77
569	Fiscal Flycatcher	34.18	41	91.11	18.75	425	80.04	-11.07
570	Common Sandpiper	4.79	20	44.44	6.67	177	33.33	-11.11
571	Marsh Owl	1.97	27	60.00	8.33	259	48.78	-11.22
572	Grey Heron	21.84	44	97.78	25	459	86.44	-11.34
573	Eurasian Hobby	0.92	8	17.78	1.34	33	6.21	-11.56
574	Cape Longclaw	15.41	40	88.89	66.67	410	77.21	-11.68

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
575	African Paradise-Flycatcher	19.92	33	73.33	15.38	324	61.02	-12.32
576	Willow Warbler	15.52	37	82.22	12.95	370	69.68	-12.54
577	Mandarin Duck	1.52	6	13.33	0.88	4	0.75	-12.58
578	Red-knobbed Coot	61.84	44	97.78	54.55	452	85.12	-12.66
579	Goliath Heron	1.99	24	53.33	9.09	216	40.68	-12.66
580	Verreaux's Eagle	1.88	12	26.67	4.21	74	13.94	-12.73
581	White-throated Swallow	34.90	45	100.00	31.25	463	87.19	-12.81
582	African Wattled Lapwing	49.07	44	97.78	24.5	450	84.75	-13.03
583	Three-banded Plover	17.24	42	93.33	27.27	426	80.23	-13.11
584	Bar-throated Apalis	9.09	27	60.00	9.09	249	46.89	-13.11
585	Lesser Flamingo	5.35	12	26.67	6.9	72	13.56	-13.11
586	Rock Dove	74.19	45	100.00	23.67	460	86.63	-13.37
587	Red-chested Cuckoo	9.41	37	82.22	18.18	365	68.74	-13.48
588	Kurrichane Buttonquail	0.42	11	24.44	2.39	58	10.92	-13.52
589	Spotted Flycatcher	7.69	41	91.11	18.18	412	77.59	-13.52
590	Booted Eagle	0.29	9	20.00	1.49	34	6.40	-13.60
591	African Jacana	5.22	21	46.67	8.99	174	32.77	-13.90
592	Common Starling	1.07	8	17.78	2.71	20	3.77	-14.01

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
593	Marsh Sandpiper	2.99	17	37.78	7.26	126	23.73	-14.05
594	Swallow-tailed Bee-eater	0.22	10	22.22	4.76	43	8.10	-14.12
595	African Firefinch	0.78	17	37.78	5.56	124	23.35	-14.43
596	Olive Thrush	0.45	9	20.00	1.59	29	5.46	-14.54
597	Wailing Cisticola	1.13	20	44.44	8.81	158	29.76	-14.69
598	Black-winged Lapwing	0.36	8	17.78	1.05	16	3.01	-14.76
599	Speckled Mousebird	66.67	45	100.00	28.57	452	85.12	-14.88
600	Pied Crow	50.00	45	100.00	41.28	452	85.12	-14.88
601	Cape White-eye	64.98	44	97.78	36	440	82.86	-14.92
602	Cape Shoveler	7.19	28	62.22	18.18	251	47.27	-14.95
603	Cape Grassbird	1.45	19	42.22	12.5	144	27.12	-15.10
604	Bokmakierie	11.44	36	80.00	30.84	344	64.78	-15.22
605	Cape Teal	4.13	18	40.00	9.09	131	24.67	-15.33
606	Greater Flamingo	9.57	20	44.44	12.73	153	28.81	-15.63
607	Lesser Striped Swallow	10.55	35	77.78	28.57	329	61.96	-15.82
608	Yellow-billed Egret	2.46	29	64.44	8.33	256	48.21	-16.23
609	Pied Avocet	11.84	19	42.22	8.33	138	25.99	-16.23
610	Black-headed Oriole	6.29	29	64.44	17.39	255	48.02	-16.42

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
611	Black-backed Puffback	17.64	26	57.78	18.88	219	41.24	-16.53
612	White-bellied Sunbird	42.22	39	86.67	42.86	372	70.06	-16.61
613	Sand Martin	0.52	13	28.89	3.45	65	12.24	-16.65
614	Burchell's Coucal	15.52	35	77.78	17.65	324	61.02	-16.76
615	African Pied Wagtail	0.29	14	31.11	6.61	76	14.31	-16.80
616	Tawny-flanked Prinia	58.33	45	100.00	33.33	440	82.86	-17.14
617	African Palm-Swift	58.33	45	100.00	29.77	440	82.86	-17.14
618	Sedge Warbler	0.75	12	26.67	3.67	50	9.42	-17.25
619	African Sacred Ibis	75.00	45	100.00	34.92	435	81.92	-18.08
620	Black Kite	0.42	11	24.44	2	33	6.21	-18.23
621	Common House-Martin	2.44	31	68.89	6.67	268	50.47	-18.42
622	Streaky-headed Seedeater	19.20	34	75.56	13.79	303	57.06	-18.49
623	Little Egret	10.00	41	91.11	16.67	385	72.50	-18.61
624	Maccoa Duck	4.48	16	35.56	7.14	90	16.95	-18.61
625	Pied Kingfisher	6.65	39	86.67	13.33	360	67.80	-18.87
626	Kurrichane Thrush	5.98	28	62.22	15.49	230	43.31	-18.91
627	Glossy Ibis	30.83	42	93.33	22.73	393	74.01	-19.32
628	Cape Robin-Chat	75.81	44	97.78	32.23	416	78.34	-19.44

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
629	Woodland Kingfisher	4.84	26	57.78	16	203	38.23	-19.55
630	Cardinal Woodpecker	11.22	34	75.56	10.42	297	55.93	-19.62
631	Village Weaver	1.60	26	57.78	8.33	201	37.85	-19.92
632	African Hoopoe	37.37	44	97.78	18.42	408	76.84	-20.94
633	African Green-Pigeon	3.77	17	37.78	6.67	88	16.57	-21.21
634	African Rail	1.13	20	44.44	7.69	123	23.16	-21.28
635	Malachite Kingfisher	5.26	35	77.78	10.34	299	56.31	-21.47
636	Barn Owl	2.25	26	57.78	6.25	191	35.97	-21.81
637	Brown-throated Martin	15.84	44	97.78	21.05	403	75.89	-21.88
638	White Stork	1.68	26	57.78	5.88	190	35.78	-22.00
639	Rosy-faced Lovebird	1.03	10	22.22	2.08	1	0.19	-22.03
640	Common Moorhen	56.55	45	100.00	25	413	77.78	-22.22
641	Red-collared Widowbird	13.73	39	86.67	18.18	341	64.22	-22.45
642	Garden Warbler	1.96	17	37.78	3.33	81	15.25	-22.52
643	Red-chested Flufftail	1.74	19	42.22	5.67	99	18.64	-23.58
644	Amethyst Sunbird	33.26	39	86.67	18.18	334	62.90	-23.77
645	Southern Pochard	8.40	34	75.56	12	275	51.79	-23.77
646	Great Crested Grebe	7.86	24	53.33	9.09	155	29.19	-24.14

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
647	African Black Swift	1.06	24	53.33	4.35	152	28.63	-24.71
648	Spotted Thick-knee	38.90	44	97.78	15.38	387	72.88	-24.90
649	African Darter	18.07	43	95.56	19.05	375	70.62	-24.93
650	Lesser Honeyguide	9.93	33	73.33	8.33	256	48.21	-25.12
651	White-breasted Cormorant	13.16	42	93.33	16.67	362	68.17	-25.16
652	Half-collared Kingfisher	0.87	17	37.78	3.12	67	12.62	-25.16
653	Black Sparrowhawk	4.47	20	44.44	4	98	18.46	-25.99
654	Peregrine Falcon	1.44	15	33.33	2.38	39	7.34	-25.99
655	Giant Kingfisher	5.83	31	68.89	8.55	225	42.37	-26.52
656	Spotted Eagle-Owl	4.39	24	53.33	5.88	142	26.74	-26.59
657	Karoo Thrush	78.29	43	95.56	20	360	67.80	-27.76
658	Common Swift	1.06	25	55.56	4.26	142	26.74	-28.81
659	Long-crested Eagle	1.66	19	42.22	5.56	64	12.05	-30.17
660	Black Crake	2.60	37	82.22	12.54	274	51.60	-30.62
661	Green-backed Heron	6.55	31	68.89	8.7	203	38.23	-30.66
662	Greater Honeyguide	3.70	31	68.89	7.14	203	38.23	-30.66
663	European Honey-Buzzard	1.29	21	46.67	3.03	85	16.01	-30.66
664	Ovambo Sparrowhawk	6.36	24	53.33	4.55	120	22.60	-30.73

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
665	Pied Starling	10.45	37	82.22	23.81	273	51.41	-30.81
666	African Harrier-Hawk	3.11	23	51.11	3.24	106	19.96	-31.15
667	Brown-backed Honeybird	4.45	24	53.33	4.17	115	21.66	-31.68
668	Lesser Swamp-Warbler	25.49	45	100.00	21.68	361	67.98	-32.02
669	Fairy Flycatcher	2.33	25	55.56	5	123	23.16	-32.39
670	Cape Weaver	4.04	33	73.33	7.69	214	40.30	-33.03
671	Orange-breasted Waxbill	4.35	34	75.56	8.33	225	42.37	-33.18
672	African Black Duck	17.84	40	88.89	9.68	291	54.80	-34.09
673	Hottentot Teal	5.00	25	55.56	6.67	112	21.09	-34.46
674	Red-throated Wryneck	8.57	39	86.67	12.9	277	52.17	-34.50
675	Red-headed Finch	19.66	42	93.33	13.33	312	58.76	-34.58
676	Rock Martin	19.61	37	82.22	8.33	251	47.27	-34.95
677	Black Heron	3.25	30	66.67	7.63	166	31.26	-35.40
678	Grey Go-away-bird	80.39	43	95.56	77.02	318	59.89	-35.67
679	Yellow-billed Kite	1.82	30	66.67	5.88	163	30.70	-35.97
680	Red-winged Starling	17.04	36	80.00	13.25	233	43.88	-36.12
681	Purple Heron	7.14	43	95.56	9.35	313	58.95	-36.61
682	Horus Swift	1.21	28	62.22	4.08	132	24.86	-37.36

S/No	Common Name	Urban Median	Urban Range of species (No. of pentads)	Percentage Urban Range of species	Rural Median	Rural Range of species (No. of pentads)	Percentage Rural Range of specie	Percentage Range Difference for species
683	Bronze Mannikin	20.17	32	71.11	8.57	178	33.52	-37.59
684	Fulvous Duck	3.41	29	64.44	8.17	142	26.74	-37.70
685	Squacco Heron	3.34	38	84.44	9.05	246	46.33	-38.12
686	African Reed-Warbler	11.11	39	86.67	8.63	254	47.83	-38.83
687	Mountain Wheatear	4.27	33	73.33	9.09	183	34.46	-38.87
688	Common Peacock	2.28	22	48.89	3.23	52	9.79	-39.10
689	Marsh Warbler	4.08	31	68.89	5.56	154	29.00	-39.89
690	Little Bittern	2.28	28	62.22	5	105	19.77	-42.45
691	Little Sparrowhawk	4.55	29	64.44	4.44	107	20.15	-44.29
692	Little Rush-Warbler	12.89	41	91.11	10.71	245	46.14	-44.97
693	Black-crowned Night-Heron	5.47	36	80.00	6.25	179	33.71	-46.29
694	Great Reed-Warbler	1.80	33	73.33	5.26	133	25.05	-48.29
695	African Purple Swamphen	7.46	39	86.67	11.76	203	38.23	-48.44
696	Rose-ringed Parakeet	9.58	25	55.56	1.92	13	2.45	-53.11
697	Thick-billed Weaver	34.24	42	93.33	12.73	210	39.55	-53.79
698	Mallard Duck	4.98	32	71.11	4.97	90	16.95	-54.16
699	Grey-headed Gull	25.14	42	93.33	16.67	199	37.48	-55.86
700	African Olive-Pigeon	24.79	35	77.78	5.77	89	16.76	-61.02

Chapter Three

Should the Devon Grasslands be an IBA?

A comparison of the avifauna between the Devon Grasslands and surrounding habitats in Gauteng-Mpumalanga

Abstract

The Important Bird Area (IBA) programme of BirdLife international uses standardized criteria to select and designate sites of global significance for bird conservation. These criteria are largely qualitative or at best semi-quantitative. The Devon Grasslands in South Africa was designated an IBA in 2014. Using a novel algorithm, this chapter uses bird distribution data from SABAP2 to show quantitatively that the Devon Grasslands (12 pentads) is distinctly different from the surrounding grassland areas (44 pentads). 234 bird species were recorded in four or more of the 56 pentads. 32 species showed a strong preference for the 12 pentads in Devon Grasslands while only six species preferred the surrounding pentads. None of these six bird species was Red Listed while seven of the 32 species preferring the Devon Grasslands are Red Listed. These results show that Devon Grasslands differs markedly from its surrounding areas, and that it is of conservation importance in the region. They also support the decision to designate the Devon Grasslands as an IBA. The quantitative algorithm developed in this chapter can also be used to assess the extent to which an area proposed for special conservation status is distinct from the surrounding areas.

Introduction

Although a site might meet the selection criteria to warrant its designation as an important site for biodiversity conservation, the nagging question remains: How different is the selected site from the neighbouring countryside? In other words, there is a need to find a quantitative measure to support the qualitative criteria used in the assessment of a site for a special conservation status. The Important Bird and Biodiversity Areas (IBAs) programme is an example of a conservation project which selects and designates sites (IBAs) of global significance for bird conservation using globally standardized criteria, but which are nevertheless largely qualitative or at best semi-quantitative (Marnewick et al., 2015a).

The Devon Grasslands is one of 124 IBAs in South Africa (Marnewick et al., 2015a). It straddles the border of Gauteng and Mpumalanga provinces and was designated as an IBA in 2014 by BirdLife South Africa. The selection of this IBA was based on the BirdLife International A1 criteria which take into account the occurrence in the region of trigger bird species – in the case of Devon Grasslands, Blue Crane *Anthropoides paradiseus* and Secretarybird *Sagitarius serpentarius* (Marnewick et al., 2015b). In terms of conservation planning for Gauteng, the part of the IBA which is within the province is considered to consist of either Critical Biodiversity Area or Ecological Support Area (Compaan, 2011).

In this chapter, I aim to show quantitatively that the Devon Grasslands area is distinctly different from the surrounding grassland areas. This case study develops a novel quantitative algorithm that can be used to assess the extent to which an area proposed for special conservation status is distinct from the surrounding countryside. In this example, the application is to an IBA, but the same approach could also be used for deciding whether a proposed site should be declared as a protected area. The algorithm makes use of the database of the Second Southern African Bird Atlas Project (SABAP2) which has extensive bird data covering the Devon Grasslands IBA and surrounding areas.

Methods

Study site

Devon Grasslands IBA is located on the eastern border of Gauteng province, and extends into Mpumalanga province of South Africa. The town of Devon (26.36° S, 28.79° E) lies to the north and the IBA extends to an area 7 km east of Balfour and 5 km north of Greylingstad. The total land area is 75 330 ha (Fig. 3.1). The Devon Grasslands IBA status is listed as unprotected (Marnewick et al., 2015b). The main habitat type is the Soweto Highveld Grassland which is characterized by medium to high, dense, tufted grasses mainly dominated by *Themeda triandra* (Mucina et al., 2006).

The major disturbance factor to the integrity of biodiversity and habitat of Devon Grasslands IBA is fragmentation caused by an extensive and well used road network. Another key disturbance factor that threatens local biodiversity in the IBA is habitat transformation driven by agricultural practices such as crop plantation, planted pastures and livestock grazing (Marnewick et al., 2015b).

Statistical analysis

I summarized the checklists for each of the pentads within the study area, extracted from the database of the Second Southern African Bird Atlas Project (SABAP2). The spatial unit for SABAP2 fieldwork is the pentad, five minutes of latitude (c. 9.2 km) by five minutes of longitude (c. 8.2 km). Each pentad is identified by a code, derived from the coordinates of the north-western corner of the pentad. A summary of SABAP2 is provided in Chapter One; an in-depth discussion of the protocol and conceptual background can be found in Harebottle et al. (2007), Loftie-Eaton (2014, 2015), Underhill and Brooks (2014) and Underhill (2016). Checklists for each pentad were collected by citizen scientists following the SABAP2 protocol; lists require a minimum of two hours' intensive field work and the objective is to make them as comprehensive as possible (Underhill 2016). For this analysis, I selected the 12 pentads which fell largely inside the Devon Grasslands IBA (usually referred as the "Inside area"), and 44 surrounding pentads, referred to as the "Outside area". Checklists submitted between July 2007 and August 2015 were included in the analysis.

The number of pentads in which a species was recorded was counted for both the Inside and the Outside areas, and expressed as a percentage (out of 12 and 44, respectively). The difference between these percentages was calculated for each species. The species were sorted on these differences. Species with large positive differences occurred in a large proportion of the pentads inside the Devon Grasslands area and in a small proportion of the pentads in the Outside area. If the difference was negative, the species occurred widely in the Outside area rather than in the Inside. This is the algorithm that can be used to compare the species composition of two areas.

Results

The number of completed checklists submitted for each of the 56 pentads in the study area ranged from a minimum of 11 to a maximum of 535. The Devon Grasslands IBA was covered by 12 (Inside area) of the 56 pentads while the remaining 44 (Outside pentads) pentads covered the area surrounding Devon Grasslands IBA. The number of species recorded in four or more of the 56 pentads in the study area was 234, of which 33 species occurred in every one of the 56 pentads. For these 33 species, the percentage range difference was zero. Three further species had percentage range differences of zero; two (White-backed Duck *Thalassornis leuconotus* and Cinnamon-breasted Bunting *Emberiza tahapisi*) occurred in 25% of the pentads in Devon Grasslands and outside and one (Ruff *Philomachus pugnax*) in 50% of the pentads in Devon Grasslands and Outside (Appendix 3.1).

A total of 32 species had positive percentage range differences exceeding 25% (Table 3.1). At the other end of the occurrence range scale, only six species (Wood Sandpiper *Tringa glareola*, Rock Martin *Ptyonoprogne fuligula*, White-winged Tern *Chlidonias leucopterus*, African Hoopoe *Upupa africana*, Neddicky *Cisticola fulvicapilla*, Giant Kingfisher *Megaceryle maxima*) had a negative percentage range differences less than –25%, meaning they were recorded in larger percentages of pentads Outside compared to Inside the Devon Grasslands (Table 3.2). 72 species had positive percentage range differences between 0% and 25% and 89 species had negative percentage range differences between 0% and –25%.

The 195 species with percentage range differences between –25% and +25% were considered as species which show little or no preference for habitat choice between the Inside and Outside areas. This leaves 38 species which showed marked preference for habitat choice either for the Devon Grasslands (i.e. the Inside) or for the Outside habitats. These are split into 32 species which showed a preference for the Devon Grasslands habitat and six which showed a preference for the habitats Outside. I obtained similar results if I varied the cut-off point from 25%. For example, at a 20% cut-off point, 41 species preferred the Devon Grasslands habitat and 17 the Outside habitat.

Four species (Greater Kestrel *Falco rupicoloides*, Secretarybird *Sagittarius serpentarius*, Blue Korhaan *Eupodotis caerulescens* and Yellow Canary *Serinus flaviventris*) occurred in all 12 Inside pentads (100%) (Table 3.3). In the 44 pentads of the Outside area, the number of pentads these species occurred is was 20 (50%), 24 (55%), 24 (55%) and 31 (71%) respectively; the percentage range differences were thus 50%, 45%, 45% and 29% respectively. The Blue Crane showed the largest difference in percentage range, 92%, occurring in 11 of the 12 Inside pentads and in eight (18%) of the 44 Outside pentads. The remaining Inside species which had positive percentage range differences of 50% or greater were Greater Kestrel *Falco rupicoloides*, African Marsh-Harrier *Circus ranivorus*, Cape Crow *Corvus capensis* and Pink-billed Lark *Spizocorys conirostris*, occurring in 12, 10, 9 and 9 of the 12 Inside pentads, respectively. These yielded percentage range differences of 50%, 52%, 55% and 50%, respectively. Table 3.3 lists the other species which showed positive percentage range differences of 25% or greater in favour of Inside pentads.

At the other end of the range spectrum, six species showed a preference for the Outside pentads (Table 3.2). For these species, the percentage range difference was negative. Of these, only one species had a percentage range difference of –25% or smaller (i.e. more negative). Wood Sandpiper occurred in 33 (75%) of the 44 Outside pentads (75%) and in six of the 12 Inside pentads (50%) giving it a percentage range difference of –25%. This was the most negative percentage range difference of the species which showed preference for Outside pentads.

Of the 32 bird species which showed a marked preference for Inside the Devon Grasslands IBA, seven are included in the Regional Red List of threatened species (Taylor et al., 2015) (Table 3.3) (Fig. 3.1). The six species which showed a preference for Outside are all classified by Taylor et al. (2015) as being of Least Concern. Of the 32 species with an Inside preference, Wattled Crane is Critically Endangered, two species (Black Harrier and African Marsh-Harrier) are Endangered, three species (Secretarybird, Lanner Falcon *Falco biarmicus* and Blue Crane) are Vulnerable and two species (Black-winged Pratincole *Glareola nordmanni* and Greater Flamingo

Phoenicopterus roseus) are Near-Threatened. A further six of the 32 Inside species (Jackal Buzzard *Buteo rufofuscus*, Blue Korhaan, Spike-heeled Lark *Chersomanes albofasciata*, Sickle-winged Chat *Cercomela sinuata*, Yellow Canary and Pink-billed Lark) are listed in Taylor et al., (2015) as “endemic and near endemic species” and which therefore should be given special conservation interest. These species have at least 90% of their global range restricted to Lesotho, South Africa and Swaziland. These species are mostly habitat or biome specifics making them of regional priority conservation concern (Taylor et al., 2015, Appendix D). Five of the seven Inside species on the Regional Red List are also included in the Global Red List: Blue Crane, Secretarybird, Black Harrier *Circus maurus* and Wattled Crane *Bugeranus carunculatus* (Vulnerable), and Black-winged Pratincole (Near-Threatened) (Taylor et al.,2015).

Discussion

As far as I am aware, this is the first implementation of an algorithm to directly compare the "conservation value" of an area with its neighborhood. In this chapter, the algorithm was applied to an IBA and its surroundings as a case study.

The IBA programme aims to identify and delimit sites of conservation importance to birds, and designate these sites using mainly qualitative criteria (Marnewick et al., 2015a, b). The concept is that these IBA sites differ considerably from the surrounding areas. However, little quantitative research has been carried out to demonstrate how IBAs differ in terms of biodiversity value from the surrounding areas. One major challenge to closing this gap in knowledge besides limited funds is the paucity of relevant data (Reyes et al., 2001, Collen et al., 2009, Marnewick et al., 2015a). Here, I used a novel algorithm and the SABAP2 data to show quantitatively that the Devon Grasslands IBA is distinct from its surrounding areas.

Should the Devon Grasslands be an IBA?

The key question for this chapter was, to apply the algorithm developed within it, to investigate whether the Devon Grasslands is appropriately designated an IBA in relation to its surrounding area. The results obtained in this chapter strongly supports Devon Grasslands as distinctly richer compared to its neighborhood in terms of bird species composition (Tables 3.1 and 3.2). Devon Grasslands (12 pentads) recorded 32 bird species which showed an occurrence preference for the IBA, whereas only six bird species occurred in more numbers in the 44 neighbouring pentads that made up the Outside area. Based on the percentage range preference of occurrence of the bird species in the study site, there is a clear indication supporting the fact that Devon Grasslands has a greater bird diversity than the surrounding areas.

Results from this chapter further show the Inside pentads of the Devon Grasslands IBA hold regular presence of both globally and regionally threatened species of conservation concern while no bird species of that category were recorded in the Outside pentads. Furthermore, the SABAP2 bird data used in this research were extracted from the decade-long database (2007–ongoing). The long time-frame of these data validates the concept of regular presence used in Criterion A1 of the BirdLife International IBA protocol (Marnewick et al., 2015). The presence of bird species of global and regional conservation concern Inside Devon Grasslands, gives further support to the IBA status of Devon Grasslands.

The Criterion A1 upon which Devon Grasslands IBA was established states: “The site regularly holds significant numbers of a globally threatened species, or other species of global conservation concern. The regular presence of a Critically Endangered or Endangered bird species at a site, irrespective of population size, is regarded as sufficient to propose the site as an IBA. The regular presence of a Vulnerable or Near-Threatened bird species at a site, subject to population size, is also sufficient to propose a site as an IBA” (Marnewick et al., 2015a). This statement is mainly qualitative with some quantitative components. The results in this chapter serves to give quantitative support to BirdLife International’s Criterion A1’s designation of Devon Grasslands as an IBA.

Furthermore, six species with a preference for the Devon Grasslands pentads are considered species of special conservation interest by Taylor et al. (2015) although they are not in any of the IUCN threat categories. These six species fall under the category of endemic and near endemic species (Fig. 3.1). This means they have at least 90% of their global range restricted to Lesotho, South Africa and Swaziland. These species are mostly biome-restricted species (Marnewick et al., 2015). Therefore, giving conservation priority to these species in Devon Grasslands will play a vital role in the regional survival of these species. Other factors such as climate change, urbanization, habitat fragmentation further increase the potential threats faced by the endemics and near endemics.

Therefore, the presence of endemic and near endemic species in Devon Grasslands and none on the Outside pentads serves to add credence to the conservation value of the Devon Grasslands and its designation as an IBA. One of these six species, Sickle-winged Chat, is a trigger species for Category A3 (biome-restricted species). The quantitative algorithm used in this chapter has provided crucial results that highlight the extent to which the Devon Grasslands is distinguished markedly from its surrounding area in terms of its importance to avian conservation.

Broader uses for the algorithm

This algorithm can be used to gain insights into conservation planning in at least three useful ways. First, it can be used in the way in which it was applied in this chapter, to ask the question whether a pre-defined area, such as the Devon Grasslands IBA, differs from surrounding habitat. Secondly, it can be used to compare the avifauna of two regions, as was done in Chapter Two for the rural and urban components of Greater Gauteng. Thirdly, there is the potential to use it for the selection of areas of special value to birds, such as proposed protected areas, or as proposed IBAs. The task would be to determine if there are a “distinctly different” set of pentads within a given area, such as for example a municipality or a one-degree grid cell. The algorithm could be applied repeatedly to this tract of land, with various combinations of selections of pentads for the Inside and the remainder constituting the Outside. This could be set up as an optimization problem, but it would probably be wise to simply treat it as a heuristic, to find a series of good solutions, and then to select the most interesting set of pentads, taking into account the different sets of species that occur within the various selections for the Inside. This third application of the algorithm should be investigated; it was beyond the scope of this research project.

The minimal data required for application of this algorithm also need investigation. For this chapter, each of the pentads had a minimum of 11 checklists (Ainsley, 2016), so the species lists for each pentad would be a reasonably complete representation of the regularly occurring species (Harrison and Martinez 1995). An interpretation of Figure 4 of Harrison and Martinez (1995) suggests that the minimal data needs per pentad are probably about four checklists. This could be investigated by subsampling the dataset from the analysis done in this chapter, and finding the breakdown point, at which the analysis provides results which make no intuitive sense.

Conclusions.

A central question for this chapter being should Devon Grasslands be an IBA has been answered. Bird data support the designation of Devon Grasslands as an IBA as the algorithm used helped to highlight how different the IBA is to surrounding areas. This was made possible due to the available large and mid-term data from SABAP2.

I have also shown that in areas where sufficiently large volumes of data are available, the importance of protected areas such as the IBAs can be demonstrated quantitatively using the approach used in this research. This offers strong support for the qualitative and semi-quantitative criteria used in the IBA site selection process and status designation. Southern Africa presents us with an ideal case where long-term data (SABAP2) is available in large volumes. I have used the Devon Grasslands IBA in this research as an example to show how the bird species composition is distinctly different from the surrounding areas as an important area of conservation concern particularly for birds.

The results of this research can be extended and applied towards other conservation goals. For example, with large enough volumes of data, we can monitor species in an area. This can enable us detect changes in species abundance, composition and distribution (Ferraro et al., 2006). Monitoring species in the IBA is crucial to ensuring that conservation targets and goals are meet as well as detecting trends in species richness, abundance and diversity within the IBA. Medium to long term data such as SABAP2 are important for any meaningful monitoring. Unless we develop methods to monitor, quantify and document subtle and overt changes in biodiversity, we will not be able to tell whether we are losing biodiversity until it is too late.

I have also shown that the algorithm used in this chapter can be used in other ways to gain insights into conservation planning besides its application as shown in this chapter. Further areas of potential application of the algorithm used in this chapter can be investigated including the application of the algorithm to find other hotspots for biodiversity conservation in the region as well as further investigation into the minimum number of checklists needed to produce reliable results for a pentad, as discussed above.

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Fig. 1: Google maps image showing the outline of Devon Grasslands IBA

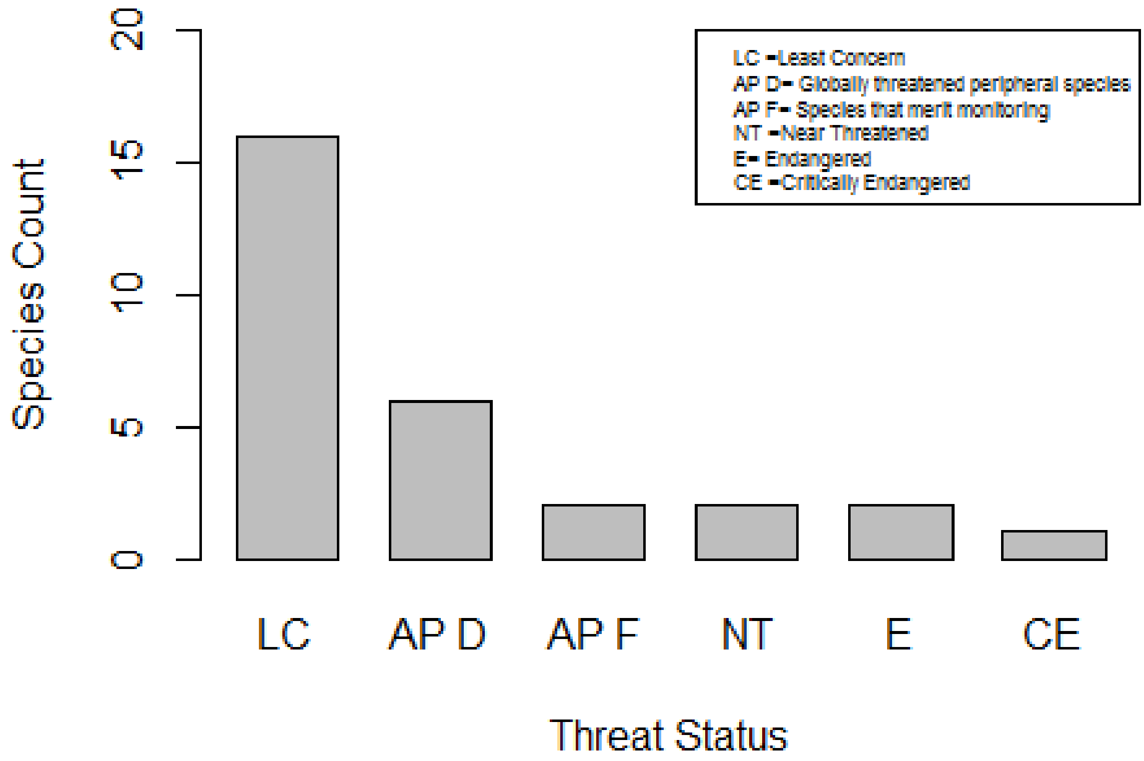

Fig 3.1: Regional IUCN threat status of bird species which showed a preference for inside Devon Grasslands IBA.

Table 3.1: Bird species showing 25% or larger percentage range difference with a preference for being within Devon Grasslands IBA.

Rank	Common name	Total range	Devon Range	Percentage Devon Range	Devon Median reporting rate	Percentage range difference
1	Blue Crane	19	11	91.7	15.8	73.5
2	Cape Crow	18	9	75.0	35.1	54.5
3	African Marsh-Harrier	24	10	83.3	10.2	51.5
4	Pink-billed Lark	20	9	75.0	15.8	50.0
5	Greater Kestrel	34	12	100.0	25.6	50.0
6	Jackal Buzzard	16	8	66.7	5.3	48.5
7	Montagu's Harrier	16	8	66.7	8.4	48.5
8	Secretarybird	36	12	100.0	14.8	45.5
9	Blue Korhaan	36	12	100.0	41.6	45.5
10	Spike-heeled Lark	33	11	91.7	13.5	41.7
11	Pied Avocet	24	9	75.0	10.8	40.9
12	Black-chested Snake-Eagle	10	6	50.0	2.7	40.9
13	White Stork	29	10	83.3	6.2	40.2
14	Black Harrier	6	5	41.7	18.2	39.4
15	Common Ostrich	26	9	75.0	7.1	36.4
16	Pale-crowned Cisticola	17	7	58.3	6.9	35.6
17	Cape Teal	22	8	66.7	10.0	34.8
18	Black-winged Pratincole	27	9	75.0	11.0	34.1
19	Chestnut-backed Sparrowlark	27	9	75.0	5.4	34.1
20	Rock Kestrel	32	10	83.3	22.7	33.3
21	Wattled Crane	4	4	33.3	12.0	33.3
22	Lanner Falcon	19	7	58.3	9.1	31.1
23	Harlequin Quail	5	4	33.3	3.7	31.1
24	Sickle-winged Chat	5	4	33.3	2.7	31.1

Rank	Common name	Total range	Devon Range	Percentage Devon Range	Devon Median reporting rate	Percentage range difference
25	Kittlitz's Plover	29	9	75.0	16.0	29.5
26	Red-collared Widowbird	29	9	75.0	4.0	29.5
27	Yellow Canary	43	12	100.0	12.4	29.5
28	Black-necked Grebe	11	5	41.7	9.1	28.0
29	Spotted Eagle-Owl	12	5	41.7	6.9	25.8
30	Barn Owl	17	6	50.0	9.8	25.0
31	Hamerkop	31	9	75.0	10.8	25.0
32	Greater Flamingo	31	9	75.0	34.5	25.0

Table 3.2: Bird species showing larger percentage range difference with a preference for Outside habitats of Devon Grasslands IBA.

Rank	Common Name	Sum Range	Outside Range	Percentage Range Outside	Outside Median Reporting Rate	Percentage Range difference
1	Wood Sandpiper	39	33	75.0	13.3	–25.0
2	Rock Martin	22	20	45.5	10.0	–28.8
3	White-winged Tern	18	17	38.6	11.1	–30.3
4	African Hoopoe	18	17	38.6	14.3	–30.3
5	Neddicky	19	18	40.9	12.9	–32.6
6	Giant Kingfisher	16	16	36.4	13.3	–36.4

Table 3.3: Regional IUCN threat status of bird species which showed a preference for being either within the Devon Grasslands IBA or Outside areas by 25% or larger percentage range difference. Species for which a threat status is not shown are classified as Least Concern.

Rank	Common name	Species' total range	Percentage range difference	Species regional IUCN threat status	Species' site preference
1	Blue Crane	19	73.5	Vulnerable	Devon Grasslands
2	Cape Crow	18	54.5		Devon Grasslands
3	African Marsh-Harrier	24	51.5	Endangered	Devon Grasslands
4	Pink-billed Lark	20	50.0		Devon Grasslands
5	Greater Kestrel	34	50.0		Devon Grasslands
6	Jackal Buzzard	16	48.5		Devon Grasslands
7	Montagu's Harrier	16	48.5		Devon Grasslands
8	Secretarybird	36	45.5	Vulnerable	Devon Grasslands
9	Blue Korhaan	36	45.5		Devon Grasslands
10	Spike-heeled Lark	33	41.7		Devon Grasslands
11	Pied Avocet	24	40.9		Devon Grasslands
12	Black-chested Snake-Eagle	10	40.9		Devon Grasslands
13	White Stork	29	40.2		Devon Grasslands
14	Black Harrier	6	39.4	Endangered	Devon Grasslands
15	Common Ostrich	26	36.4		Devon Grasslands
16	Pale-crowned Cisticola	17	35.6		Devon Grasslands
17	Cape Teal	22	34.8		Devon Grasslands
18	Black-winged Pratincole	27	34.1	Near Threatened	Devon Grasslands
19	Chestnut-backed Sparrowlark	27	34.1		Devon Grasslands
20	Rock Kestrel	32	33.3		Devon Grasslands
21	Wattled Crane	4	33.3	Critically Endangered	Devon Grasslands
22	Lanner Falcon	19	31.1	Vulnerable	Devon Grasslands

Rank	Common name	Species' total range	Percentage range difference	Species regional IUCN threat status	Species' site preference
23	Harlequin Quail	5	31.1		Devon Grasslands
24	Sickle-winged Chat	5	31.1		Devon Grasslands
25	Kittlitz's Plover	29	29.5		Devon Grasslands
26	Red-collared Widowbird	29	29.5		Devon Grasslands
27	Yellow Canary	43	29.5		Devon Grasslands
28	Black-necked Grebe	11	28.0		Devon Grasslands
29	Spotted Eagle-Owl	12	25.8		Devon Grasslands
30	Barn Owl	17	25.0		Devon Grasslands
31	Hamerkop	31	25.0		Devon Grasslands
32	Greater Flamingo	31	25.0	Near Threatened	Devon Grasslands
33	Wood Sandpiper	39	–25.0		Outside areas
34	Rock Martin	22	–28.8		Outside areas
35	White-winged Tern	18	–30.3		Outside areas
36	African Hoopoe	18	–30.3		Outside areas
37	Neddicky	19	–32.6		Outside areas
38	Giant Kingfisher	16	–36.4		Outside areas

Appendix 3.1: List of bird species occurring at Devon Grasslands and surrounding Outside areas.

Rank	Common Name	Percentage range for Devon Grasslands	Percentage range for Outside areas	Percentage range difference
1	Blue Crane	91.67	18.18	73.48
2	Cape Crow	75.00	20.45	54.55
3	African Marsh-Harrier	83.33	31.82	51.52
4	Pink-billed Lark	75.00	25.00	50.00
5	Greater Kestrel	100.00	50.00	50.00
6	Jackal Buzzard	66.67	18.18	48.48
7	Montagu's Harrier	66.67	18.18	48.48
8	Secretarybird	100.00	54.55	45.45
9	Blue Korhaan	100.00	54.55	45.45
10	Spike-heeled Lark	91.67	50.00	41.67
11	Pied Avocet	75.00	34.09	40.91
12	Black-chested Snake-Eagle	50.00	9.09	40.91
13	White Stork	83.33	43.18	40.15
14	Black Harrier	41.67	2.27	39.39
15	Common Ostrich	75.00	38.64	36.36
16	Pale-crowned Cisticola	58.33	22.73	35.61
17	Cape Teal	66.67	31.82	34.85
18	Black-winged Pratincole	75.00	40.91	34.09
19	Chestnut-backed Sparrowlark	75.00	40.91	34.09
20	Rock Kestrel	83.33	50.00	33.33
21	Wattled Crane	33.33	0.00	33.33
22	Lanner Falcon	58.33	27.27	31.06
23	Harlequin Quail	33.33	2.27	31.06
24	Sickle-winged Chat	33.33	2.27	31.06
25	Kittlitz's Plover	75.00	45.45	29.55
26	Red-collared Widowbird	75.00	45.45	29.55

Rank	Common Name	Percentage range for Devon Grasslands	Percentage range for Outside areas	Percentage range difference
27	Yellow Canary	100.00	70.45	29.55
28	Black-necked Grebe	41.67	13.64	28.03
29	Spotted Eagle-Owl	41.67	15.91	25.76
30	Barn Owl	50.00	25.00	25.00
31	Hamerkop	75.00	50.00	25.00
32	Greater Flamingo	75.00	50.00	25.00
33	South African Shelduck	58.33	34.09	24.24
34	Common Quail	100.00	77.27	22.73
35	Marsh Owl	100.00	77.27	22.73
36	Cape Glossy Starling	100.00	77.27	22.73
37	White-bellied Korhaan	25.00	2.27	22.73
38	Orange-breasted Waxbill	75.00	52.27	22.73
39	Melodious Lark	33.33	11.36	21.97
40	Sentinel Rock-Thrush	25.00	4.55	20.45
41	Maccoa Duck	58.33	38.64	19.70
42	Yellow-billed Stork	41.67	22.73	18.94
43	Lesser Striped Swallow	41.67	22.73	18.94
44	Common Greenshank	66.67	47.73	18.94
45	Mountain Wheatear	66.67	50.00	16.67
46	Common Sandpiper	50.00	34.09	15.91
47	Lesser Kestrel	25.00	9.09	15.91
48	African Grass-Owl	25.00	9.09	15.91
49	Great Egret	75.00	59.09	15.91
50	Capped Wheatear	100.00	84.09	15.91
51	Fan-tailed Widowbird	100.00	84.09	15.91
52	Goliath Heron	58.33	43.18	15.15
53	Tawny-flanked Prinia	41.67	27.27	14.39
54	Steppe Buzzard	91.67	77.27	14.39
55	Orange River Francolin	100.00	86.36	13.64

Rank	Common Name	Percentage range for Devon Grasslands	Percentage range for Outside areas	Percentage range difference
56	Pied Crow	50.00	36.36	13.64
57	White-browed Sparrow-Weaver	75.00	61.36	13.64
58	White-breasted Cormorant	83.33	70.45	12.88
59	Lesser Flamingo	41.67	29.55	12.12
60	African Harrier-Hawk	16.67	4.55	12.12
61	Fulvous Duck	50.00	38.64	11.36
62	Pied Kingfisher	75.00	63.64	11.36
63	Spotted Thick-knee	100.00	88.64	11.36
64	Cloud Cisticola	100.00	88.64	11.36
65	Curlew Sandpiper	33.33	22.73	10.61
66	Red-backed Shrike	33.33	22.73	10.61
67	Common Moorhen	91.67	81.82	9.85
68	Rock Dove	91.67	81.82	9.85
69	Cape Shoveler	100.00	90.91	9.09
70	African Snipe	100.00	90.91	9.09
71	Brown-throated Martin	100.00	90.91	9.09
72	African Quailfinch	100.00	90.91	9.09
73	Common Swift	25.00	15.91	9.09
74	Plain-backed Pipit	25.00	15.91	9.09
75	Marsh Sandpiper	50.00	40.91	9.09
76	African Darter	83.33	75.00	8.33
77	Cape Weaver	33.33	25.00	8.33
78	African Black Swift	16.67	9.09	7.58
79	Village Weaver	16.67	9.09	7.58
80	Red-headed Finch	75.00	68.18	6.82
81	African Spoonbill	100.00	93.18	6.82
82	House Sparrow	100.00	93.18	6.82
83	White-winged Widowbird	100.00	93.18	6.82

Rank	Common Name	Percentage range for Devon Grasslands	Percentage range for Outside areas	Percentage range difference
84	Pallid Harrier	25.00	18.18	6.82
85	African Wattled Lapwing	91.67	86.36	5.30
86	Spur-winged Goose	100.00	95.45	4.55
87	Common Waxbill	100.00	95.45	4.55
88	Hottentot Teal	25.00	20.45	4.55
89	Purple Heron	66.67	63.64	3.03
90	Lesser Swamp-Warbler	66.67	63.64	3.03
91	Southern Pochard	91.67	88.64	3.03
92	Little Grebe	100.00	97.73	2.27
93	African Sacred Ibis	100.00	97.73	2.27
94	Three-banded Plover	100.00	97.73	2.27
95	Red-capped Lark	100.00	97.73	2.27
96	Barn Swallow	100.00	97.73	2.27
97	Grey-winged Francolin	8.33	6.82	1.52
98	European Roller	8.33	6.82	1.52
99	Common Scimitarbill	8.33	6.82	1.52
100	Sand Martin	8.33	6.82	1.52
101	Fairy Flycatcher	8.33	6.82	1.52
102	Desert Cisticola	16.67	15.91	0.76
103	Amur Falcon	91.67	90.91	0.76
104	White-backed Duck	25.00	25.00	0.00
105	Cinnamon-breasted Bunting	25.00	25.00	0.00
106	Ruff	50.00	50.00	0.00
107	Reed Cormorant	100.00	100.00	0.00
108	Black-headed Heron	100.00	100.00	0.00
109	Cattle Egret	100.00	100.00	0.00
110	Hadeda Ibis	100.00	100.00	0.00
111	Egyptian Goose	100.00	100.00	0.00
112	Yellow-billed Duck	100.00	100.00	0.00

Rank	Common Name	Percentage range for Devon Grasslands	Percentage range for Outside areas	Percentage range difference
113	Red-billed Teal	100.00	100.00	0.00
114	Black-shouldered Kite	100.00	100.00	0.00
115	Swainson's Spurfowl	100.00	100.00	0.00
116	Helmeted Guineafowl	100.00	100.00	0.00
117	Red-knobbed Coot	100.00	100.00	0.00
118	Crowned Lapwing	100.00	100.00	0.00
119	Blacksmith Lapwing	100.00	100.00	0.00
120	Speckled Pigeon	100.00	100.00	0.00
121	Red-eyed Dove	100.00	100.00	0.00
122	Cape Turtle-Dove	100.00	100.00	0.00
123	Laughing Dove	100.00	100.00	0.00
124	Greater Striped Swallow	100.00	100.00	0.00
125	African Stonechat	100.00	100.00	0.00
126	Zitting Cisticola	100.00	100.00	0.00
127	Levaillant's Cisticola	100.00	100.00	0.00
128	Black-chested Prinia	100.00	100.00	0.00
129	Cape Wagtail	100.00	100.00	0.00
130	African Pipit	100.00	100.00	0.00
131	Cape Longclaw	100.00	100.00	0.00
132	Common Fiscal	100.00	100.00	0.00
133	Cape Sparrow	100.00	100.00	0.00
134	Southern Masked-Weaver	100.00	100.00	0.00
135	Red-billed Quelea	100.00	100.00	0.00
136	Southern Red Bishop	100.00	100.00	0.00
137	Yellow-crowned Bishop	100.00	100.00	0.00
138	Long-tailed Widowbird	100.00	100.00	0.00
139	Pin-tailed Whydah	100.00	100.00	0.00
140	Yellow-billed Kite	8.33	9.09	–0.76
141	European Bee-eater	8.33	9.09	–0.76

Rank	Common Name	Percentage range for Devon Grasslands	Percentage range for Outside areas	Percentage range difference
142	Buffy Pipit	8.33	9.09	–0.76
143	Long-tailed Paradise-Whydah	8.33	9.09	–0.76
144	Great Crested Grebe	41.67	43.18	–1.52
145	Red-throated Wryneck	66.67	68.18	–1.52
146	Diderick Cuckoo	91.67	93.18	–1.52
147	Comb Duck	16.67	18.18	–1.52
148	African Jacana	16.67	18.18	–1.52
149	African Paradise-Flycatcher	16.67	18.18	–1.52
150	Yellow-fronted Canary	50.00	52.27	–2.27
151	Yellow-billed Egret	83.33	86.36	–3.03
152	Whiskered Tern	83.33	86.36	–3.03
153	Little Bittern	8.33	11.36	–3.03
154	African Rail	8.33	11.36	–3.03
155	Lilac-breasted Roller	8.33	11.36	–3.03
156	Black-crowned Night-Heron	41.67	45.45	–3.79
157	Black-collared Barbet	66.67	70.45	–3.79
158	Grey Heron	91.67	95.45	–3.79
159	White-faced Duck	91.67	95.45	–3.79
160	South African Cliff-Swallow	91.67	95.45	–3.79
161	Wailing Cisticola	25.00	29.55	–4.55
162	Wing-snapping Cisticola	75.00	79.55	–4.55
163	Namaqua Dove	58.33	63.64	–5.30
164	Cuckoo Finch	8.33	13.64	–5.30
165	Bokmakierie	41.67	47.73	–6.06
166	African Fish-Eagle	16.67	22.73	–6.06
167	Black-winged Stilt	66.67	72.73	–6.06
168	Dark-capped Bulbul	66.67	72.73	–6.06

Rank	Common Name	Percentage range for Devon Grasslands	Percentage range for Outside areas	Percentage range difference
169	White-throated Swallow	91.67	97.73	–6.06
170	Common Myna	91.67	97.73	–6.06
171	Black-throated Canary	91.67	97.73	–6.06
172	White-bellied Sunbird	8.33	15.91	–7.58
173	Common House-Martin	33.33	40.91	–7.58
174	Banded Martin	33.33	40.91	–7.58
175	White-rumped Swift	91.67	100.00	–8.33
176	African Olive-Pigeon	0.00	9.09	–9.09
177	Grey Go-away-bird	0.00	9.09	–9.09
178	Alpine Swift	0.00	9.09	–9.09
179	Marsh Warbler	0.00	9.09	–9.09
180	Cape Grassbird	0.00	9.09	–9.09
181	Little Stint	50.00	59.09	–9.09
182	Common Ringed Plover	8.33	18.18	–9.85
183	Horus Swift	8.33	18.18	–9.85
184	Little Rush-Warbler	8.33	18.18	–9.85
185	Long-billed Pipit	8.33	18.18	–9.85
186	Cape Bunting	8.33	18.18	–9.85
187	Fiscal Flycatcher	41.67	52.27	–10.61
188	Lesser Grey Shrike	16.67	27.27	–10.61
189	Green-backed Heron	0.00	11.36	–11.36
190	Mocking Cliff-Chat	0.00	11.36	–11.36
191	Green Wood-Hoopoe	58.33	70.45	–12.12
192	Black Heron	8.33	20.45	–12.12
193	Acacia Pied Barbet	8.33	20.45	–12.12
194	Great Reed-Warbler	8.33	20.45	–12.12
195	Common Redstart	33.33	45.45	–12.12
196	African Black Duck	41.67	54.55	–12.88
197	Rufous-Naped Lark	50.00	63.64	–13.64
198	Cape Robin-Chat	50.00	63.64	–13.64

Rank	Common Name	Percentage range for Devon Grasslands	Percentage range for Outside areas	Percentage range difference
199	Cardinal Woodpecker	0.00	13.64	–13.64
200	Bar-throated Apalis	0.00	13.64	–13.64
201	Yellow Bishop	0.00	13.64	–13.64
202	Little Egret	75.00	88.64	–13.64
203	Glossy Ibis	83.33	97.73	–14.39
204	Familiar Chat	8.33	22.73	–14.39
205	Malachite Sunbird	8.33	22.73	–14.39
206	African Palm-Swift	33.33	47.73	–14.39
207	Red-faced Mousebird	33.33	47.73	–14.39
208	Malachite Kingfisher	41.67	56.82	–15.15
209	Caspian Tern	0.00	15.91	–15.91
210	Amethyst Sunbird	0.00	15.91	–15.91
211	Cape Canary	0.00	15.91	–15.91
212	African Reed-Warbler	25.00	40.91	–15.91
213	Streaky-headed Seedeater	8.33	25.00	–16.67
214	Squacco Heron	33.33	50.00	–16.67
215	African Red-eyed Bulbul	16.67	34.09	–17.42
216	Pied Starling	25.00	43.18	–18.18
217	Spotted Flycatcher	16.67	36.36	–19.70
218	Red-winged Starling	0.00	20.45	–20.45
219	Grey-headed Gull	33.33	54.55	–21.21
220	Speckled Mousebird	33.33	54.55	–21.21
221	Red-chested Cuckoo	8.33	29.55	–21.21
222	Willow Warbler	16.67	38.64	–21.97
223	Anteating Chat	66.67	88.64	–21.97
224	Black Crake	0.00	22.73	–22.73
225	African Purple Swamphen	25.00	47.73	–22.73
226	Crested Barbet	50.00	72.73	–22.73

Rank	Common Name	Percentage range for Devon Grasslands	Percentage range for Outside areas	Percentage range difference
227	Little Swift	75.00	97.73	–22.73
228	Wattled Starling	33.33	56.82	–23.48
229	Wood Sandpiper	50.00	75.00	–25.00
230	Rock Martin	16.67	45.45	–28.79
231	White-winged Tern	8.33	38.64	–30.30
232	African Hoopoe	8.33	38.64	–30.30
233	Neddicky	8.33	40.91	–32.58
234	Giant Kingfisher	0.00	36.36	–36.36

Chapter Four

How different is the Suikerbosrand Nature Reserve from its surrounding areas?

Abstract.

Important Bird Areas (IBAs) are designated primarily for the conservation of bird species in an area. The methods used for IBA selection are mainly qualitative rather than quantitative. A question of interest that can be posed when considering sites selected for biodiversity conservation is how different it is from the neighbouring area. Developing quantitative measures to support the qualitative criteria therefore becomes a valuable exercise. Suikerbosrand Nature Reserve is one of 124 IBAs in South Africa, located about 50 km south of Johannesburg within Greater Gauteng. In this chapter, I provided a qualitative measure using bird abundance and distribution data from the SABAP2 database to show how different the Suikerbosrand Nature Reserve is from the surrounding area. I used the SABAP2 bird atlas data for the four pentads covering Suikerbosrand and 32 surrounding pentads. A total of 409 bird species occurred in four or more of the 36 pentads in the study area. 147 species showed a strong preference for the pentads inside Suikerbosrand and 13 species showed a percentage range preference for the outside pentads. Of the 147 species which preferred Suikerbosrand, 51 species are biome-restricted to either the grassland or savanna biomes. None of the species which preferred the Outside areas are biome-restricted. Furthermore, 13 of the 147 species which preferred Suikerbosrand are included in the Regional Red List. Two of the 13 species which preferred the Outside area are Red Listed, both Near-threatened. The results show that Suikerbosrand differs from its surrounding areas.

Introduction

A key strategy for the protection of biodiversity from habitat loss and degradation has been the establishment and maintenance of protected areas which are the core units of *in situ* conservation (Eken et al., 2004). A protected area is a defined geographical space, recognized and managed, with legal backing or other effective means to achieve long-term conservation of nature with associated ecosystem services and cultural values within the defined area (IUCN, 2008). Important Bird Areas (IBAs) are designated specifically for the bird species (trigger species) contained in an area which by extension benefits the biodiversity in the area (Mwangi et al., 2010). Generally, the methods used for assessing and selection of a site for biodiversity conservation are rarely been quantitative (Prendergast et al., 1999, Grooves et al., 2002). Most of the available methods used are qualitative or at best semi-quantitative (Faith and Walker, 1996, Margules et al., 1988, Arcos et al., 2012, Marnewick et al., 2015). A question of interest that often is posed when considering selection criteria for sites for biodiversity conservation is how different is the selected site from the neighbouring area (Marnewick et al., 2015)? Offering a quantitative measure to support the qualitative criteria used in the process of assessment and selection of a site for a special conservation status therefore becomes imperative. In this chapter, I aim to provide a qualitative measure using bird abundance and distribution data from the SABAP2 database to show how different the Suikerbosrand Nature Reserve is from its surrounding areas. In Chapter 3, I answered this question positively for the Devon Grasslands IBA; in this short chapter I replicate the analysis but, considered a smaller IBA which is a quarter of the size of Devon Grasslands.

Suikerbosrand Nature Reserve is one of 124 IBAs in South Africa, located about 50 km south of Johannesburg. Suikerbosrand was declared an IBA using Criterion C1 for species conservation concern (Marnewick et al., 2015b). The Criterion C1 stipulates for sites that regularly holds significant numbers of nationally threatened bird species to be designated an IBA status. The location and IBA designation of Suikerbosrand Nature Reserve makes it an interesting area for study, given the small size of the reserve and the anthropogenic and urbanization pressures the IBA faces.

In this chapter, I aim to show quantitatively that Suikerbosrand Nature Reserve differs from the surrounding areas in terms of bird species supported. The research in this chapter applies the same quantitative method as used in Chapter 3. This quantitative method can be applied as a tool for biodiversity conservation given limited resources vs unlimited needs conundrum. The algorithm used in this chapter, similar to Chapter 3 is based on the database of the Second Southern African Bird Atlas Project (SABAP2) which has extensive bird data covering the Suikerbosrand Nature Reserve IBA and surrounding areas.

Materials and methods

Study site

Located in the Gauteng province of South Africa, Suikerbosrand Nature Reserve (Fig. 4.1) lies between the towns of Heidelberg and Meyerton, in the industrialized Highveld of Gauteng about 50 km south of Johannesburg. It was proclaimed a nature reserve in 1974 with an area of 11,959 ha, originally made up of nine farms. Over the years additional farms north of the original reserve have been purchased and incorporated into the reserve. In 2015, Suikerbosrand Nature Reserve had an area of 17,950 ha. It has IBA status (Marnewick et al., 2015a).

Suikerbosrand Nature Reserve contains habitats suitable for several bird species of conservation concern: the globally threatened Melodious Lark *Mirafra cheniana* Blue Korhaan *Eupodotis caerulescens* and the Secretarybird *Sagittarius serpentarius* as well as regionally threatened species the African Grass Owl *Tyto capensis,* and White-bellied Korhaan *Eupodotis senegalensis.* Suikerbosrand Nature Reserve is dominated by the Suikerbos Ridge which runs from east to west reaching a maximum height of about 1,918m above sea level. This ridge is the source of seasonal streams and there are steep cliffs and gorges running into well-wooded kloofs (a steep-sided, wooded ravine or valley is known as kloof in South Africa.). The Suikerbosrand Nature Reserve is on the Highveld, with an altitude range of between 1,500 to 1,918m a.s.l and it is dominated by grassland habitats (Marnewick et al., 2015a).

The Suikerbosrand IBA has a fully protected status and the reserve is managed by the Gauteng Department of Agriculture and Rural Development (GDARD). It is intensively used for environmental education, outdoor recreation activities and resource management (Marnewick et al., 2015).

Analysis

Data for the analysis were generated from summarized bird lists for the study area which was extracted from the database of the Second Southern African Bird Atlas Project (SABAP2). Checklists submitted between June 2007 and August 2015 were used. I grouped the data into two groups. The first group is the area within Suikerbosrand Nature Reserve also designated an IBA and second group was the area outside Suikerbosrand Nature Reserve. Data were collected at the spatial unit of a pentad according to the SABAP2 fieldwork protocol (Chapter One). A pentad measures five minutes of latitude (c. 9.2 km) by five minutes of longitude (c. 8.2 km) (Underhill and Brooks, 2016).

The study area is made up of a total of 36 pentads, with four of these falling into the Suikerbosrand Nature Reserve (hereafter referred to as 'Suikerbosrand') and the remaining 32 pentads falling in the area immediately surrounding Suikerbosrand (hereafter referred to as the 'Outside') on all sides of the reserve, the selection of the outside pentads is to give a comparative basis for the comparison of occurrence and distribution range of bird species, I selected up to two layers of pentads away from the reserve to include as much area as possible away from the reserve that has been affected by urbanization and increased human population in the region and also capture the avifaunal abundance and richness in this areas as compared to within the Suikerbosrand Nature reserve.

The number of pentads for which a species occurred was recorded was totalled for both Suikerbosrand and Outside areas. This represented the distribution or occurrence range for each species in Suikerbosrand and Outside areas. As in Chapter Three, the proportion of pentads containing each species in both Suikerbosrand and Outside areas was calculated, by dividing by 4 and 32 respectively, and expressed as percentage range. The difference between the percentage range in Suikerbosrand and outside was calculated for each species and expressed as percentage range difference. This indicates the preference of the species for Suikerbosrand and Outside areas.

The analysis in this research is based only on the counts of species from presence/absence data of species in a pentad, as was the case in Chapter Three.

Results

A total of 409 species occurred in four or more of the 36 pentads in the study area (Appendix 4.1). The number of species recorded within the four Suikerbosrand pentads was 342, and within the 32 Outside pentads was 378. The number of species recorded in both areas was 311; 31 species occurred only in the Suikerbosrand pentads, and 67 only in the Outside pentads (Appendix 4.1).

Because there were only four pentads within Suikerbosrand, the percentage range occurrence could only take on one of five values: 0%, 25%, 50%, 75% and 100%. Using the same cut-off criterion as in Chapter Three for showing distinct preference for inside or outside areas, a total of 249 species had percentage range differences between 25% and –25% (Appendix 4.1). A total of 51 species occurred in every one of the 36 pentads covering the study area (Appendix 4.1). For these species, the percentage range differences are zero given they have 100% range for both inside Suikerbosrand and Outside areas. Three more species; Bronze Mannikin *Lonchura cucullata*, Ovambo Sparrowhawk *Accipiter ovampensis* and Orange River Francolin *Scleroptila levaillantoides* had percentage range differences of zero; two (Bronze Mannikin and Ovambo Sparrowhawk) occurred in 25% of the pentads inside Suikerbosrand and 25% of the outside pentads and one (Orange River Francolin) in 75% of the pentads inside Suikerbosrand and 75% of outside pentads. A total of 112 species had positive percentage range differences less than 25% and 83 species had negative percentage range differences larger than –25%. These 249 bird species are considered as indifferent to being inside Suikerbosrand or the Outside area (Appendix 4.1). They are not considered further in this chapter.

There were 147 species with percentage range differences of 25% or larger, and considered to have a preference for being inside Suikerbosrand (Table 4.1), and 13 species with percentage range differences of –25% or less (Table 4.2), and considered to have a preference for the Outside area. Twelve of the 13 species listed in Table 4.2 are associated with wetlands, mainly large wetlands, a habitat type that does not occur within Suikerbosrand. The only terrestrial species of Table 4.2 was Namaqua Dove *Oena capensis*, a species of “Least Concern”.

The African Grass-Owl showed the largest difference in percentage range (Table 4.1). It occurred in all four Suikerbosrand pentads giving it 100% range inside Suikerbosrand while of the 34 Outside pentads, it occurred in one pentad (3% Outside range), giving it a percentage range difference of 97%. Secretarybird – a bird species of regional conservation concern (classified as being regionally Vulnerable) and one of the species whose occurrence in Suikerbosrand contributed in the designation of Suikerbosrand as an IBA (Marnewick et al., 2015), had a 100% occurrence in Suikerbosrand with percentage range difference of 63%.

Of the 147 species in Table 4.1, which may be considered as the Suikerbosrand species, 13 are included in the IUCN Regional Red List of bird species of conservation concern (Taylor et al., 2015). The Cape Vulture *Gyps coprotheres* is listed as being “Endangered”. It had a percentage range of 50% with a reporting rate of 1.61 inside Suikerbosrand while Outside it has a percentage range of 3% and a reporting rate of 0.3. Six bird species have a threat status of “Vulnerable”: Verreaux’s Eagle *Aquila verreauxii* (75% vs 13% range, 2% vs 13% Reporting rate), Yellow-Breasted Pipit *Anthus chloris* (50% vs 0% range, 2% reporting rate), White-bellied Korhaan *Eupodotis senegalensis* (50% vs 3% range, 0.8% vs 3% reporting rate) and Lanner Falcon *Falco biarmicus* (75% vs 3% Range, 1% vs 5% reporting rate). Another six species are categorized as being “Near Threatened”: Red-footed Falcon *Falco vespertinus* (100% vs 16% range, 2% vs 5% reporting rate), African Rock Pipit *Anthus crenatus* (75% vs 0% range, 2% reporting rate), Pallid Harrier *Circus macrourus* (50% vs 3% range, 2% vs 4% reporting rate), Maccoa Duck *Oxyura maccoa* (50% vs 25% range, 0.5% vs 8% reporting rate), Marabou Stork *Leptoptilos crumenifer* (25% vs 0% range, 1% reporting rate) and Violet Wood-hoopoe *Phoeniculus damarensis* (25% vs 0%, 0.6% reporting rate).

On the other hand, of the 13 bird species showing marked preference for the Outside area (Table 4.2), only two bird species, both flamingos- Lesser flamingo *Phoeniconaias minor* and Greater Flamingo- *Phoenicopterus roseus*, were included in the 2015 Regional Red List, with both listed as being Near Threatened.

Furthermore, of the 147 species categorized as the Suikerbosrand species(Table 4.1), 51 are recognised as biome-restricted species to either the grassland or savanna biomes (Hockey et al., 2005). Biome-specific bird species are species that have been observed and identified to live with some levels of permanence within a large-scale biotic community which corresponds to a climatic region (biome). Of the 51 biome specific Suikerbosrand species, 38 species were listed as savanna biome-specifics while 13 further species were listed as grassland biome-specifics (Table 4.1). The grassland specific species includes the African Grass-Owl which had a percentage range difference of 96.88% in favour of Suikerbosrand where it has a reporting rate of 3% vs. 1% for Outside, Eastern Long-billed Lark *Certhilauda semitorquata* with a percentage range difference of 81% and a reporting rate 11% for Suikerbosrand vs. 3% for Outside areas and Montagu's Harrier which had a percentage range difference of 75% and a reporting rate of 2% for Suikerbosrand vs. 0% for Outside. The savanna biome-specific species included Sentinel Rock-Thrush *Monticola explorator*, which has a percentage range difference of 90.63% and a reporting rate of 12.62% for Suikerbosrand vs. 4% for Outside, Red-winged Francolin *Francolinus levaillantii* which had a percentage range difference of 78% and a reporting rate of 3% for Suikerbosrand vs. 3% for Outside, and Arrow-marked Babbler *Turdoides jardineii* which had a percentage range difference of 62% and a reporting rate of 2% for Suikerbosrand vs. 4% for Outside. Table 4.1 lists the biome-restricted status of other Suikerbosrand species. At the other end of the spectrum, none of the 13 Outside species was recognised as a biome-specific bird species.

Discussion

How different is Suikerbosrand Reserve IBA from surrounding areas?

Suikerbosrand is an IBA with a fully protected status and in this chapter, I applied the same algorithm has used in Chapter Three. An important aim of this study was to investigate whether this approach would produce meaningful results in an area as small as Suikerbosrand (17,950 ha) which is contained in just four SABAP2 pentads.

The approach used here to answer this question provides an application of this quantitative algorithm which can be used to confirm whether or not an area is different and the extent of its difference from its surroundings, similar to the application on a different IBA with a different size and circumstances (Chapter Three). The results in this chapter make a solid quantitative case in support of Suikerbosrand being different from the surrounding areas and worthy of its designation as an IBA in terms of Category C1. The BirdLife International criterion C1 designates any site that holds significant numbers of bird species that are classified as nationally Threatened with extinction, to be a site of important conservation status to birds and other biodiversity in the region. It also designates any site where regular presence of Critically Endangered or Endangered bird species, irrespective of population size, as an IBA" (Marnewick et al., 2015). It further states that the "regular presence of a Critically Endangered or Endangered bird species at a site, irrespective of population size, is sufficient to propose the site as an IBA" (Marnewick et al., 2015). The C1 criteria as described and employed by BirdLife International to designate sites such as Suikerbosrand as an IBA is essentially qualitative, and at best semi-quantitative. Therefore, it is worth noting that the algorithm used in this chapter, which is quantitative gives support to the BirdLife International's semi–quantitative criteria in designating Suikerbosrand as a site that differs markedly from its immediate surroundings in terms of avifauna richness.

Suikerbosrand is strikingly different from the surrounding areas in terms of the C1 criteria. The reserve has more species classified as nationally threatened with extinction (Taylor et al., 2015) than the Outside areas. Of the 13 bird species listed under the IUCN threat categories, the Cape Vulture is listed as nationally endangered. No Outside species had a threat status.

Furthermore, considering the distribution of Biome-restricted species between Suikerbosrand and Outside areas, we again see Suikerbosrand being strikingly different from the Outside areas. Thirty-four percent of the Suikerbosrand species are to varying degrees biome-restricted for either the grassland or the savanna biomes. I focused mainly on the grassland and savanna biomes because these two are the dominant biomes in Greater Gauteng (Allan et al., 1997, Marnewick et al., 2015). The Greater Gauteng is roughly divided into two halves of near equal size by the latitude 26°S line. The half north of latitude 26°S is dominated by the savanna biome while the half south of 26˚S is dominated by grassland biome (Allan et al., 1997). Comparatively, of the 13 Outside species, none is biome restricted to either the grassland or savanna biomes. This difference in biome restricted species reveals Suikerbosrand Nature reserve as different from the Outside surrounding areas in terms of avian species richness and the conservation significance of the avifauna.

Appendix 4.1 shows the bird species from the study area which either occurred exclusively Inside Suikerbosrand or exclusively Outside From this results it becomes clear that Suikerbosrand holds a larger number of bird species exclusively (29) than the Outside (three) and more bird species also displayed an occurrence preference for Suikerbosrand (147) than the Outside areas (13). Considering this result in terms of the difference in size between Suikerbosrand (4 pentads) vs. the Outside area (32 pentads), it puts into perspective in the light that 29 vs. three species occurred exclusively within the smaller area (Suikerbosrand).

An understanding of Island biogeography (MacArthur and Wilson, 1967) can help in explaining this observed difference in general species richness as well as the difference in species showing exclusive site occurrence. Natural reserves, surrounded by altered habitat as is the case with Suikerbosrand, resembles a system of islands from the point of view of species restricted to the natural habitats within the reserve (Diamond, 1975). The theory of Island biogeography posits that for such island reserves, the number of species it can hold at equilibrium is a function of its area and its isolation. Larger reserves, and reserves located close to other reserves, can hold more species (Diamond, 1975). The Suikerbosrand surely qualifies as an island given its location within Greater Gauteng. This could explain the higher avifauna richness and exclusive occurrence within Suikerbosrand.

Many studies that examined nature reserves have mostly considered the richness, diversity and abundance of biodiversity within the reserve (Diamond, 1975, Myers et al., 2000, Fernández-Juricic and Jokimäki, 2001, Grooves et al., 2002). The algorithm approach as I have used here to compare the richness and abundance of biodiversity within a reserve and that of the immediate surrounding has not been used by anyone else as far as I can tell.

Another likely explanation as to why Suikerbosrand differs so markedly from the surrounding areas can be deduced from the large diversity of micro-habitats occurs within Suikerbosrand, in spite of its relatively small area (Marnewick et al., 2015). The reserve is dominated by a ridge rising up to 1,900m a.s.l running along its east to west axis. The annual rainfall in the reserve varies considerably over short distances with the north receiving more rainfall than the south. This local variation in rainfall patterns, along with the complex landscape relief, results in the mosaic of vegetation types and micro-habitats occurring in the reserve such as well-wooded kloofs, steep cliffs and rocky outcrops, open grassy plains, wooded bushveld, aloe forest, etc (Marnewick et al., 2015). On the outside of Suikerbosrand however, even though there might be a variety of micro–habitats such as the agricultural lands and mining sites as well as parks and gardens within residential areas (Marnewick et al., 2015), the high human population density and disturbance by urbanization makes the surrounding habitats less desirable to the avifauna.

Conclusions

I set out at the beginning of this chapter to find out if Suikerbosrand IBA differs from the neighbouring areas in terms of avifauna richness and abundance. On the strength of the algorithm applied in this chapter to bird atlas data, I can say Suikerbosrand differs decisively from the neighbouring area. The results from this chapter supports the decision by BirdLife International to declare Suikerbosrand as a nature reserve. The results also provides quantitative support for the designation of Suikerbosrand as an IBA, given the difference in bird species richness and abundance as shown by preference for the area by bird species. Also, given the small size of the reserve and how different it is from the comparatively large surrounding area, it is worth noting the 'Suikerbosrand Nature Reserve, though tiny, is making a substantial contribution to the conservation of avian biodiversity in Greater Gauteng. It is also worth mentioning that a need for close monitoring of the species within the reserve is crucial to the long term conservation of the region. This is given the threats faced by biodiversity in the area which includes disturbances such as unplanned fires and uncontrolled grazing and trampling by cattle. Though fire has been shown to be a tool for the management of grassland habitats, Incompatible fire and grazing regimes negatively affect the availability of suitable habitat for key bird species such as African Grass Owl.

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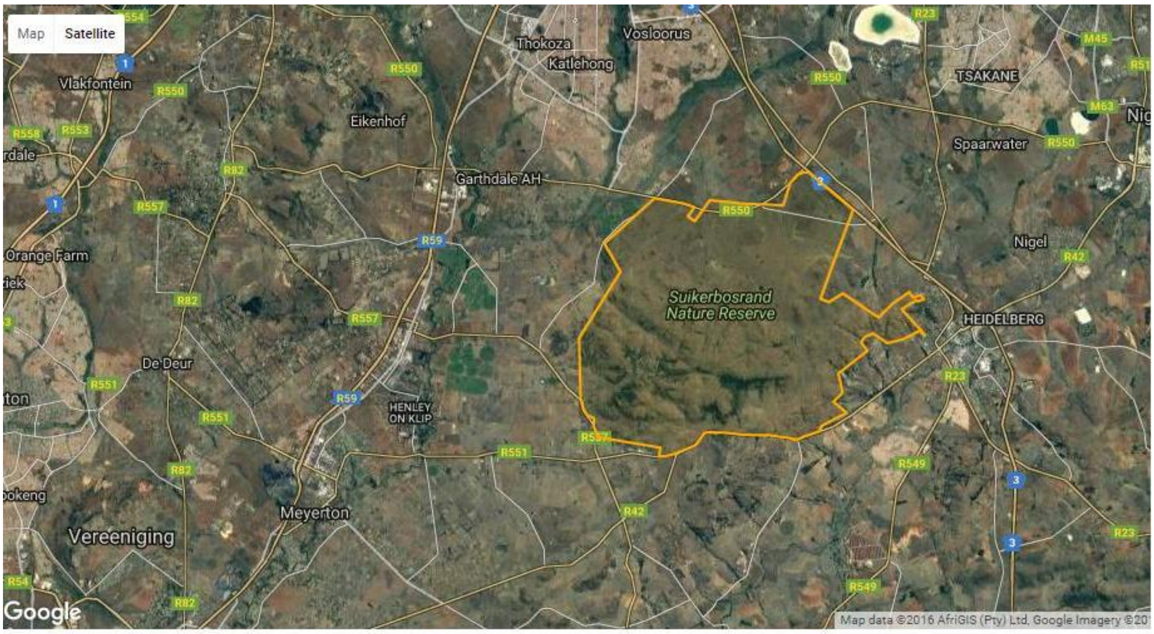

Fig 4.1: Image showing the outline of the Suikerbosrand nature reserve. (image courtesy Google maps)

Table 4.1: Bird species showing 25% or larger percentage range difference with a preference for being within the Suikerbosrand Nature Reserve. Species for which a threat status is not shown are classified as 'Least Concern'.

S/No	Common Name	S'bosrand* percentage range	S'bosrand Reporting Rate	Outside percentage range	Outside Reporting Rate	Percentage Range Difference	IBA trigger	Biome restriction
1	African Grass-Owl	100.00	3.29	3.13	1.01	96.88	Vulnerable	Biome restricted
2	Grey-winged Francolin	100.00	8.35	3.13	1.43	96.88		
3	Cuckoo Finch	100.00	4.18	6.25	1.50	93.75		
4	Sentinel Rock-Thrush	100.00	12.62	9.38	3.45	90.63		Biome restricted
5	Black-chested Snake-Eagle	100.00	4.00	12.50	2.25	87.50		
6	Brubru	100.00	8.80	12.50	5.46	87.50		
7	Cape Canary	100.00	22.82	12.50	7.23	87.50		
8	Cape Rock-Thrush	100.00	22.53	12.50	7.85	87.50		
9	Lazy Cisticola	100.00	10.02	12.50	2.74	87.50		
10	Cape Grassbird	100.00	20.26	15.63	2.22	84.38		
11	Red-footed Falcon	100.00	1.94	15.63	4.76	84.38	Near threatened	
12	Common Quail	100.00	4.84	18.75	3.52	81.25		
13	Eastern Long-billed Lark	100.00	10.65	18.75	2.50	81.25		Biome restricted
14	Chinspot Batis	100.00	6.16	21.88	11.11	78.13		
15	Lesser Grey Shrike	100.00	2.10	21.88	5.56	78.13		

S/No	Common Name	S'bosrand* percentage range	S'bosrand Reporting Rate	Outside percentage range	Outside Reporting Rate	Percentage Range Difference	IBA trigger	Biome restriction
16	Red-winged Francolin	100.00	3.09	21.88	2.78	78.13		Biome restricted
17	Mocking Cliff-Chat	100.00	20.49	25.00	10.67	75.00		
18	African Rock Pipit	75.00	2.04	0.00	0.00	75.00	Near threatened	
19	Montagu's Harrier	75.00	1.81	0.00	0.00	75.00		Biome restricted
20	Jackal Buzzard	100.00	10.54	28.13	2.86	71.88		
21	African Black Swift	100.00	2.09	31.25	2.85	68.75		
22	Cape Bunting	100.00	38.81	31.25	9.40	68.75		
23	Common Scimitarbill	100.00	2.49	31.25	5.72	68.75		
24	Kalahari Scrub-Robin	100.00	6.08	31.25	25.11	68.75		Biome restricted
25	Plain-backed Pipit	100.00	4.11	31.25	3.26	68.75		
26	Rock Kestrel	100.00	9.57	31.25	4.36	68.75		
27	Yellow Bishop	100.00	8.12	31.25	2.54	68.75		
28	Alpine Swift	75.00	0.60	6.25	1.21	68.75		
29	Garden Warbler	75.00	1.78	6.25	2.33	68.75		
30	Golden-breasted Bunting	75.00	2.96	6.25	2.17	68.75		
31	Burchell's Coucal	100.00	2.76	34.38	9.52	65.63		
32	Lesser Striped Swallow	100.00	2.84	34.38	5.26	65.63		

S/No	Common Name	S'bosrand* percentage range	S'bosrand Reporting Rate	Outside percentage range	Outside Reporting Rate	Percentage Range Difference	IBA trigger	Biome restriction
33	Southern Boubou	100.00	7.10	34.38	6.25	65.63		
34	Grey-headed Bush-Shrike	75.00	0.59	9.38	1.90	65.63		
35	Lilac-breasted Roller	75.00	0.60	9.38	2.00	65.63		
36	Common Sandpiper	100.00	1.32	37.50	5.71	62.50		
37	Long-billed Pipit	100.00	17.49	37.50	4.00	62.50		
38	Secretarybird	100.00	12.58	37.50	5.06	62.50	Vulnerable	Biome restricted
39	Arrow-marked Babbler	75.00	1.78	12.50	3.65	62.50		Biome restricted
40	Black Cuckooshrike	75.00	2.04	12.50	3.35	62.50		
41	Kurrichane Thrush	75.00	1.51	12.50	3.95	62.50		Biome restricted
42	Verreaux's Eagle	75.00	2.42	12.50	12.50	62.50	Vulnerable	
43	European Bee-eater	100.00	5.34	40.63	8.33	59.38		
44	Great Egret	100.00	2.98	40.63	7.41	59.38		
45	Spotted Eagle-Owl	100.00	1.27	40.63	6.73	59.38		
46	African Harrier-Hawk	75.00	0.60	15.63	2.51	59.38		Biome restricted
47	Greater Kestrel	75.00	0.60	15.63	7.69	59.38		Biome restricted
48	Sand Martin	75.00	5.04	15.63	3.85	59.38		

S/No	Common Name	S'bosrand* percentage range	S'bosrand Reporting Rate	Outside percentage range	Outside Reporting Rate	Percentage Range Difference	IBA trigger	Biome restriction
49	Malachite Sunbird	100.00	12.04	43.75	5.57	56.25		
50	Long-billed Crombec	75.00	3.63	18.75	2.90	56.25		
51	Melodious Lark	75.00	2.04	18.75	6.48	56.25		Biome restricted
52	Yellow-billed Kite	75.00	0.72	18.75	2.01	56.25		
53	Chestnut-vented Tit-Babbler	100.00	34.45	46.88	23.81	53.13		Biome restricted
54	Ashy Tit	75.00	2.42	21.88	11.11	53.13		Biome restricted
55	Common House-Martin	100.00	2.10	50.00	6.37	50.00		
56	Desert Cisticola	100.00	6.15	50.00	6.27	50.00		Biome restricted
57	Red-chested Cuckoo	100.00	13.64	50.00	7.85	50.00		Biome restricted
58	Red-winged Starling	75.00	10.65	25.00	7.85	50.00		
59	Orange-breasted Bush-Shrike	50.00	0.74	0.00	0.00	50.00		Biome restricted
60	Striped Kingfisher	50.00	0.45	0.00	0.00	50.00		
61	White-browed Scrub-Robin	50.00	3.56	0.00	0.00	50.00		Biome restricted
62	Yellow-bellied Eremomela	50.00	0.74	0.00	0.00	50.00		
63	Yellow-breasted Pipit	50.00	1.84	0.00	0.00	50.00	Vulnerable	Biome restricted

S/No	Common Name	S'bosrand* percentage range	S'bosrand Reporting Rate	Outside percentage range	Outside Reporting Rate	Percentage Range Difference	IBA trigger	Biome restriction
64	Marsh Owl	100.00	10.31	53.13	6.67	46.88		
65	Thick-billed Weaver	100.00	2.80	53.13	15.38	46.88		
66	European Honey-Buzzard	75.00	0.91	28.13	3.70	46.88		
67	Lesser Kestrel	75.00	1.51	28.13	4.00	46.88	Merit Monitoring	
68	Red-chested Flufftail	75.00	2.72	28.13	5.26	46.88		
69	Cape Vulture	50.00	1.61	3.13	0.25	46.88	Endangered	
70	Common Cuckoo	50.00	0.45	3.13	0.25	46.88		Biome restricted
71	Pallid Harrier	50.00	1.59	3.13	4.00	46.88	Near threatened	Biome restricted
72	Sabota Lark	50.00	4.00	3.13	4.44	46.88		Biome restricted
73	Sickle-winged Chat	50.00	2.52	3.13	1.75	46.88		
74	White-bellied Korhaan	50.00	0.81	3.13	2.99	46.88	Vulnerable	Biome restricted
75	African Reed-Warbler	100.00	4.61	56.25	15.77	43.75		
76	Banded Martin	100.00	12.56	56.25	5.84	43.75		
77	Cinnamon-breasted Bunting	100.00	19.83	56.25	12.31	43.75		Biome restricted
78	Great Reed-Warbler	75.00	0.72	31.25	5.97	43.75		
79	Lanner Falcon	75.00	1.21	31.25	4.71	43.75	Vulnerable	

S/No	Common Name	S'bosrand* percentage range	S'bosrand Reporting Rate	Outside percentage range	Outside Reporting Rate	Percentage Range Difference	IBA trigger	Biome restriction
80	Brimstone Canary	50.00	1.05	6.25	2.51	43.75		
81	Cape Eagle-Owl	50.00	0.45	6.25	2.12	43.75	Merit Monitoring	
82	Fork-tailed Drongo	50.00	1.04	6.25	2.76	43.75		
83	Golden-tailed Woodpecker	50.00	1.04	6.25	2.90	43.75		
84	Lark-like Bunting	50.00	1.35	6.25	1.15	43.75		
85	Lesser Masked-Weaver	50.00	1.17	6.25	0.44	43.75		Biome restricted
86	Marico Flycatcher	50.00	0.89	6.25	2.76	43.75		Biome restricted
87	Cape Weaver	100.00	21.83	59.38	5.26	40.63		
88	Familiar Chat	100.00	44.02	59.38	6.12	40.63		
89	African Fish-Eagle	75.00	0.60	34.38	5.88	40.63		
90	Barn Owl	75.00	1.18	34.38	3.45	40.63		
91	Green-winged Pytilia	75.00	3.32	34.38	11.11	40.63		Biome restricted
92	Horus Swift	75.00	2.11	34.38	3.85	40.63		
93	Black-backed Puffback	50.00	2.23	9.38	2.24	40.63		
94	Groundscraper Thrush	50.00	0.45	9.38	1.50	40.63		Biome restricted
95	Klaas's Cuckoo	50.00	1.49	9.38	5.24	40.63		Biome restricted

S/No	Common Name	S'bosrand* percentage range	S'bosrand Reporting Rate	Outside percentage range	Outside Reporting Rate	Percentage Range Difference	IBA trigger	Biome restriction
96	Kurrichane Buttonquail	50.00	0.66	9.38	0.63	40.63		Biome restricted
97	Pied Crow	100.00	6.32	62.50	20.11	37.50		
98	Streaky-headed Seedeater	100.00	36.49	62.50	21.74	37.50		Biome restricted
99	White-bellied Sunbird	100.00	7.23	62.50	13.12	37.50		Biome restricted
100	Wing-snapping Cisticola	100.00	23.31	62.50	14.84	37.50		Biome restricted
101	Brown-crowned Tchagra	75.00	5.14	37.50	10.43	37.50		
102	Fairy Flycatcher	75.00	13.60	37.50	4.04	37.50		
103	White-backed Mousebird	75.00	2.11	37.50	7.69	37.50		
104	Rock Martin	100.00	5.51	65.63	11.76	34.38		
105	Red-backed Shrike	75.00	5.44	40.63	4.08	34.38		Biome restricted
106	Black Sparrowhawk	50.00	0.75	15.63	2.78	34.38		
107	Brown-hooded Kingfisher	50.00	1.17	15.63	2.86	34.38		
108	Eastern Clapper Lark	100.00	4.93	68.75	10.32	31.25		Biome restricted
109	Purple Heron	100.00	8.70	68.75	7.87	31.25		
110	Wailing Cisticola	100.00	37.85	68.75	16.88	31.25		Biome restricted

S/No	Common Name	S'bosrand* percentage range	S'bosrand Reporting Rate	Outside percentage range	Outside Reporting Rate	Percentage Range Difference	IBA trigger	Biome restriction
111	Yellow-fronted Canary	100.00	7.15	68.75	7.69	31.25		Biome restricted
112	Fan-tailed Widowbird	75.00	4.53	43.75	7.85	31.25		Biome restricted
113	Jacobin Cuckoo	50.00	0.45	18.75	1.00	31.25		Biome restricted
114	Marsh Warbler	50.00	2.34	18.75	3.87	31.25		
115	Rattling Cisticola	50.00	1.93	18.75	2.50	31.25		
116	Amethyst Sunbird	75.00	2.11	46.88	11.11	28.13		Biome restricted
117	Buffy Pipit	50.00	2.25	21.88	2.78	28.13		Biome restricted
118	Orange-breasted Waxbill	100.00	4.34	75.00	8.39	25.00		
119	African Paradise-Flycatcher	75.00	8.46	50.00	7.69	25.00		
120	Lesser Honeyguide	75.00	4.08	50.00	7.69	25.00		
121	White Stork	75.00	2.04	50.00	5.72	25.00		
122	Maccoa Duck	50.00	0.51	25.00	7.70	25.00	Near threatened	
123	White-backed Duck	50.00	29.11	25.00	7.85	25.00		
124	African Barred Owlet	25.00	0.30	0.00	0.00	25.00		Biome restricted
125	African Pied Wagtail	25.00	0.60	0.00	0.00	25.00		

S/No	Common Name	S'bosrand* percentage range	S'bosrand Reporting Rate	Outside percentage range	Outside Reporting Rate	Percentage Range Difference	IBA trigger	Biome restriction
126	Anchieta's Tchagra	25.00	0.59	0.00	0.00	25.00		
127	Burchell's Starling	25.00	0.30	0.00	0.00	25.00		Biome restricted
128	Burnt-necked Eremomela	25.00	1.78	0.00	0.00	25.00		Biome restricted
129	Cape Crow	25.00	0.30	0.00	0.00	25.00		
130	Crested Francolin	25.00	0.91	0.00	0.00	25.00		Biome restricted
131	Dark-capped Yellow Warbler	25.00	0.30	0.00	0.00	25.00		
132	Grey-backed Camaroptera	25.00	1.18	0.00	0.00	25.00		Biome restricted
133	Grey-rumped Swallow	25.00	0.30	0.00	0.00	25.00		
134	Magpie Shrike	25.00	0.30	0.00	0.00	25.00		Biome restricted
135	Marabou Stork	25.00	1.44	0.00	0.00	25.00	Near threatened	
136	Pale-crowned Cisticola	25.00	5.04	0.00	0.00	25.00		Biome restricted
137	Purple Roller	25.00	1.18	0.00	0.00	25.00		Biome restricted
138	Red-billed Oxpecker	25.00	1.18	0.00	0.00	25.00		Biome restricted
139	Shelley's Francolin	25.00	0.30	0.00	0.00	25.00		

S/No	Common Name	S'bosrand* percentage range	S'bosrand Reporting Rate	Outside percentage range	Outside Reporting Rate	Percentage Range Difference	IBA trigger	Biome restriction
140	Sombre Greenbul	25.00	0.30	0.00	0.00	25.00		
141	Southern Black Flycatcher	25.00	0.30	0.00	0.00	25.00		Biome restricted
142	Southern White-faced Scops-Owl	25.00	0.59	0.00	0.00	25.00		
143	Tinkling Cisticola	25.00	0.59	0.00	0.00	25.00		
144	Violet Wood-Hoopoe	25.00	0.59	0.00	0.00	25.00	Near Threatened	
145	White-browed Robin-Chat	25.00	0.72	0.00	0.00	25.00		
146	Wire-tailed Swallow	25.00	0.72	0.00	0.00	25.00		
147	Yellow-collared Lovebird	25.00	0.59	0.00	0.00	25.00		

***S'bosrand = Suikerbosrand Nature reserve**

Table 4.2: Bird species showing 25% or larger percentage range difference with a preference for being Outside the Suikerbosrand Nature Reserve. Species for which a threat status is not shown are classified as Least Concern

Rank	Common Name	Inside Range	Inside Percentage Range	Inside Reporting Rate	Outside Range	Outside Reporting Rate	Outside Reporting Rate	Percentage Range Difference	Threat status
1	Greater Flamingo	0	0.00	0.00	19	59.38	11.11	59.38	Near threatened
2	Little Egret	2	50.00	8.32	30	93.75	15.38	43.75	
3	Whiskered Tern	2	50.00	13.12	29	90.63	8.89	40.63	
4	African Spoonbill	2	50.00	8.47	29	90.63	11.43	40.63	
5	Little Rush-Warbler	1	25.00	4.53	19	59.38	7.69	34.38	
6	Kittlitz's Plover	0	0.00	0.00	10	31.25	7.29	31.25	
7	Giant Kingfisher	1	25.00	0.59	18	56.25	7.18	31.25	
8	Curlew Sandpiper	0	0.00	0.00	9	28.13	7.14	28.13	
9	Hottentot Teal	1	25.00	0.30	17	53.13	7.69	28.13	
10	Namaqua Dove	2	50.00	2.10	25	78.13	6.12	28.13	
11	Lesser Flamingo	0	0.00	0.00	8	25.00	5.89	25.00	Near threatened
12	Little Stint	1	25.00	0.72	16	50.00	10.44	25.00	
13	Black-winged Stilt	2	50.00	8.14	24	75.00	15.98	25.00	

Appendix 4.1: List of bird species from Suikerbosrand Reserve IBA and Outside areas

S/No	Common Name	S'bosrand Range	S'bosrand Percentage Range	S'bosrand Reporting Rate	Outside Range	Outside Percentage Range	Outside Reporting Rate	Percentage Range Difference	Preference
1	African Grass-Owl	4	100.00	3.29	1	3.13	1.01	96.88	S'bosrand
2	Grey-winged Francolin	4	100.00	8.35	1	3.13	1.43	96.88	S'bosrand
3	Cuckoo Finch	4	100.00	4.18	2	6.25	1.50	93.75	S'bosrand
4	Sentinel Rock-Thrush	4	100.00	12.62	3	9.38	3.45	90.63	S'bosrand
5	Black-chested Snake-Eagle	4	100.00	4.00	4	12.50	2.25	87.50	S'bosrand
6	Brubru	4	100.00	8.80	4	12.50	5.46	87.50	S'bosrand
7	Cape Canary	4	100.00	22.82	4	12.50	7.23	87.50	S'bosrand
8	Cape Rock-Thrush	4	100.00	22.53	4	12.50	7.85	87.50	S'bosrand
9	Lazy Cisticola	4	100.00	10.02	4	12.50	2.74	87.50	S'bosrand
10	Cape Grassbird	4	100.00	20.26	5	15.63	2.22	84.38	S'bosrand
11	Red-footed Falcon	4	100.00	1.94	5	15.63	4.76	84.38	S'bosrand
12	Common Quail	4	100.00	4.84	6	18.75	3.52	81.25	S'bosrand
13	Eastern Long-billed Lark	4	100.00	10.65	6	18.75	2.50	81.25	S'bosrand
14	Chinspot Batis	4	100.00	6.16	7	21.88	11.11	78.13	S'bosrand
15	Lesser Grey Shrike	4	100.00	2.10	7	21.88	5.56	78.13	S'bosrand
16	Red-winged Francolin	4	100.00	3.09	7	21.88	2.78	78.13	S'bosrand
17	Mocking Cliff-Chat	4	100.00	20.49	8	25.00	10.67	75.00	S'bosrand
18	African Rock Pipit	3	75.00	2.04	0	0.00	0.00	75.00	S'bosrand
19	Montagu's Harrier	3	75.00	1.81	0	0.00	0.00	75.00	S'bosrand
20	Jackal Buzzard	4	100.00	10.54	9	28.13	2.86	71.88	S'bosrand
21	African Black Swift	4	100.00	2.09	10	31.25	2.85	68.75	S'bosrand
22	Cape Bunting	4	100.00	38.81	10	31.25	9.40	68.75	S'bosrand
23	Common Scimitarbill	4	100.00	2.49	10	31.25	5.72	68.75	S'bosrand
24	Kalahari Scrub-Robin	4	100.00	6.08	10	31.25	25.11	68.75	S'bosrand
25	Plain-backed Pipit	4	100.00	4.11	10	31.25	3.26	68.75	S'bosrand

26	Rock Kestrel	4	100.00	9.57	10	31.25	4.36	68.75	S'bosrand
27	Yellow Bishop	4	100.00	8.12	10	31.25	2.54	68.75	S'bosrand
28	Alpine Swift	3	75.00	0.60	2	6.25	1.21	68.75	S'bosrand
29	Garden Warbler	3	75.00	1.78	2	6.25	2.33	68.75	S'bosrand
30	Golden-breasted Bunting	3	75.00	2.96	2	6.25	2.17	68.75	S'bosrand
31	Burchell's Coucal	4	100.00	2.76	11	34.38	9.52	65.63	S'bosrand
32	Lesser Striped Swallow	4	100.00	2.84	11	34.38	5.26	65.63	S'bosrand
33	Southern Boubou	4	100.00	7.10	11	34.38	6.25	65.63	S'bosrand
34	Grey-headed Bush-Shrike	3	75.00	0.59	3	9.38	1.90	65.63	S'bosrand
35	Lilac-breasted Roller	3	75.00	0.60	3	9.38	2.00	65.63	S'bosrand
36	Common Sandpiper	4	100.00	1.32	12	37.50	5.71	62.50	S'bosrand
37	Long-billed Pipit	4	100.00	17.49	12	37.50	4.00	62.50	S'bosrand
38	Secretarybird	4	100.00	12.58	12	37.50	5.06	62.50	S'bosrand
39	Arrow-marked Babbler	3	75.00	1.78	4	12.50	3.65	62.50	S'bosrand
40	Black Cuckooshrike	3	75.00	2.04	4	12.50	3.35	62.50	S'bosrand
41	Kurrichane Thrush	3	75.00	1.51	4	12.50	3.95	62.50	S'bosrand
42	Verreaux's Eagle	3	75.00	2.42	4	12.50	12.50	62.50	S'bosrand
43	European Bee-eater	4	100.00	5.34	13	40.63	8.33	59.38	S'bosrand
44	Great Egret	4	100.00	2.98	13	40.63	7.41	59.38	S'bosrand
45	Spotted Eagle-Owl	4	100.00	1.27	13	40.63	6.73	59.38	S'bosrand
46	African Harrier-Hawk	3	75.00	0.60	5	15.63	2.51	59.38	S'bosrand
47	Greater Kestrel	3	75.00	0.60	5	15.63	7.69	59.38	S'bosrand
48	Sand Martin	3	75.00	5.04	5	15.63	3.85	59.38	S'bosrand
49	Malachite Sunbird	4	100.00	12.04	14	43.75	5.57	56.25	S'bosrand
50	Long-billed Crombec	3	75.00	3.63	6	18.75	2.90	56.25	S'bosrand
51	Melodious Lark	3	75.00	2.04	6	18.75	6.48	56.25	S'bosrand
52	Yellow-billed Kite	3	75.00	0.72	6	18.75	2.01	56.25	S'bosrand
53	Chestnut-vented Tit-Babbler	4	100.00	34.45	15	46.88	23.81	53.13	S'bosrand
54	Ashy Tit	3	75.00	2.42	7	21.88	11.11	53.13	S'bosrand

55	Common House-Martin	4	100.00	2.10	16	50.00	6.37	50.00	S'bosrand
56	Desert Cisticola	4	100.00	6.15	16	50.00	6.27	50.00	S'bosrand
57	Red-chested Cuckoo	4	100.00	13.64	16	50.00	7.85	50.00	S'bosrand
58	Red-winged Starling	3	75.00	10.65	8	25.00	7.85	50.00	S'bosrand
59	Orange-breasted Bush-Shrike	2	50.00	0.74	0	0.00	0.00	50.00	S'bosrand
60	Striped Kingfisher	2	50.00	0.45	0	0.00	0.00	50.00	S'bosrand
61	White-browed Scrub-Robin	2	50.00	3.56	0	0.00	0.00	50.00	S'bosrand
62	Yellow-bellied Eremomela	2	50.00	0.74	0	0.00	0.00	50.00	S'bosrand
63	Yellow-breasted Pipit	2	50.00	1.84	0	0.00	0.00	50.00	S'bosrand
64	Marsh Owl	4	100.00	10.31	17	53.13	6.67	46.88	S'bosrand
65	Thick-billed Weaver	4	100.00	2.80	17	53.13	15.38	46.88	S'bosrand
66	European Honey-Buzzard	3	75.00	0.91	9	28.13	3.70	46.88	S'bosrand
67	Lesser Kestrel	3	75.00	1.51	9	28.13	4.00	46.88	S'bosrand
68	Red-chested Flufftail	3	75.00	2.72	9	28.13	5.26	46.88	S'bosrand
69	Cape Vulture	2	50.00	1.61	1	3.13	0.25	46.88	S'bosrand
70	Common Cuckoo	2	50.00	0.45	1	3.13	0.25	46.88	S'bosrand
71	Pallid Harrier	2	50.00	1.59	1	3.13	4.00	46.88	S'bosrand
72	Sabota Lark	2	50.00	4.00	1	3.13	4.44	46.88	S'bosrand
73	Sickle-winged Chat	2	50.00	2.52	1	3.13	1.75	46.88	S'bosrand
74	White-bellied Korhaan	2	50.00	0.81	1	3.13	2.99	46.88	S'bosrand
75	African Reed-Warbler	4	100.00	4.61	18	56.25	15.77	43.75	S'bosrand
76	Banded Martin	4	100.00	12.56	18	56.25	5.84	43.75	S'bosrand
77	Cinnamon-breasted Bunting	4	100.00	19.83	18	56.25	12.31	43.75	S'bosrand
78	Great Reed-Warbler	3	75.00	0.72	10	31.25	5.97	43.75	S'bosrand
79	Lanner Falcon	3	75.00	1.21	10	31.25	4.71	43.75	S'bosrand
80	Brimstone Canary	2	50.00	1.05	2	6.25	2.51	43.75	S'bosrand
81	Cape Eagle-Owl	2	50.00	0.45	2	6.25	2.12	43.75	S'bosrand

82	Fork-tailed Drongo	2	50.00	1.04	2	6.25	2.76	43.75	S'bosrand
83	Golden-tailed Woodpecker	2	50.00	1.04	2	6.25	2.90	43.75	S'bosrand
84	Lark-like Bunting	2	50.00	1.35	2	6.25	1.15	43.75	S'bosrand
85	Lesser Masked-Weaver	2	50.00	1.17	2	6.25	0.44	43.75	S'bosrand
86	Marico Flycatcher	2	50.00	0.89	2	6.25	2.76	43.75	S'bosrand
87	Cape Weaver	4	100.00	21.83	19	59.38	5.26	40.63	S'bosrand
88	Familiar Chat	4	100.00	44.02	19	59.38	6.12	40.63	S'bosrand
89	African Fish-Eagle	3	75.00	0.60	11	34.38	5.88	40.63	S'bosrand
90	Barn Owl	3	75.00	1.18	11	34.38	3.45	40.63	S'bosrand
91	Green-winged Pytilia	3	75.00	3.32	11	34.38	11.11	40.63	S'bosrand
92	Horus Swift	3	75.00	2.11	11	34.38	3.85	40.63	S'bosrand
93	Black-backed Puffback	2	50.00	2.23	3	9.38	2.24	40.63	S'bosrand
94	Groundscraper Thrush	2	50.00	0.45	3	9.38	1.50	40.63	S'bosrand
95	Klaas's Cuckoo	2	50.00	1.49	3	9.38	5.24	40.63	S'bosrand
96	Kurrichane Buttonquail	2	50.00	0.66	3	9.38	0.63	40.63	S'bosrand
97	Pied Crow	4	100.00	6.32	20	62.50	20.11	37.50	S'bosrand
98	Streaky-headed Seedeater	4	100.00	36.49	20	62.50	21.74	37.50	S'bosrand
99	White-bellied Sunbird	4	100.00	7.23	20	62.50	13.12	37.50	S'bosrand
100	Wing-snapping Cisticola	4	100.00	23.31	20	62.50	14.84	37.50	S'bosrand
101	Brown-crowned Tchagra	3	75.00	5.14	12	37.50	10.43	37.50	S'bosrand
102	Fairy Flycatcher	3	75.00	13.60	12	37.50	4.04	37.50	S'bosrand
103	White-backed Mousebird	3	75.00	2.11	12	37.50	7.69	37.50	S'bosrand
104	Rock Martin	4	100.00	5.51	21	65.63	11.76	34.38	S'bosrand
105	Red-backed Shrike	3	75.00	5.44	13	40.63	4.08	34.38	S'bosrand
106	Black Sparrowhawk	2	50.00	0.75	5	15.63	2.78	34.38	S'bosrand
107	Brown-hooded Kingfisher	2	50.00	1.17	5	15.63	2.86	34.38	S'bosrand
108	Eastern Clapper Lark	4	100.00	4.93	22	68.75	10.32	31.25	S'bosrand
109	Purple Heron	4	100.00	8.70	22	68.75	7.87	31.25	S'bosrand
110	Wailing Cisticola	4	100.00	37.85	22	68.75	16.88	31.25	S'bosrand

111	Yellow-fronted Canary	4	100.00	7.15	22	68.75	7.69	31.25	S'bosrand
112	Fan-tailed Widowbird	3	75.00	4.53	14	43.75	7.85	31.25	S'bosrand
113	Jacobin Cuckoo	2	50.00	0.45	6	18.75	1.00	31.25	S'bosrand
114	Marsh Warbler	2	50.00	2.34	6	18.75	3.87	31.25	S'bosrand
115	Rattling Cisticola	2	50.00	1.93	6	18.75	2.50	31.25	S'bosrand
116	Amethyst Sunbird	3	75.00	2.11	15	46.88	11.11	28.13	S'bosrand
117	Buffy Pipit	2	50.00	2.25	7	21.88	2.78	28.13	S'bosrand
118	Orange-breasted Waxbill	4	100.00	4.34	24	75.00	8.39	25.00	S'bosrand
119	African Paradise-Flycatcher	3	75.00	8.46	16	50.00	7.69	25.00	S'bosrand
120	Lesser Honeyguide	3	75.00	4.08	16	50.00	7.69	25.00	S'bosrand
121	White Stork	3	75.00	2.04	16	50.00	5.72	25.00	S'bosrand
122	Maccoa Duck	2	50.00	0.51	8	25.00	7.70	25.00	S'bosrand
123	White-backed Duck	2	50.00	29.11	8	25.00	7.85	25.00	S'bosrand
124	African Barred Owlet	1	25.00	0.30	0	0.00	0.00	25.00	S'bosrand
125	African Pied Wagtail	1	25.00	0.60	0	0.00	0.00	25.00	S'bosrand
126	Anchieta's Tchagra	1	25.00	0.59	0	0.00	0.00	25.00	S'bosrand
127	Burchell's Starling	1	25.00	0.30	0	0.00	0.00	25.00	S'bosrand
128	Burnt-necked Eremomela	1	25.00	1.78	0	0.00	0.00	25.00	S'bosrand
129	Cape Crow	1	25.00	0.30	0	0.00	0.00	25.00	S'bosrand
130	Crested Francolin	1	25.00	0.91	0	0.00	0.00	25.00	S'bosrand
131	Dark-capped Yellow Warbler	1	25.00	0.30	0	0.00	0.00	25.00	S'bosrand
132	Grey-backed Camaroptera	1	25.00	1.18	0	0.00	0.00	25.00	S'bosrand
133	Grey-rumped Swallow	1	25.00	0.30	0	0.00	0.00	25.00	S'bosrand
134	Magpie Shrike	1	25.00	0.30	0	0.00	0.00	25.00	S'bosrand
135	Marabou Stork	1	25.00	1.44	0	0.00	0.00	25.00	S'bosrand
136	Pale-crowned Cisticola	1	25.00	5.04	0	0.00	0.00	25.00	S'bosrand
137	Purple Roller	1	25.00	1.18	0	0.00	0.00	25.00	S'bosrand

138	Red-billed Oxpecker	1	25.00	1.18	0	0.00	0.00	25.00	S'bosrand
139	Shelley's Francolin	1	25.00	0.30	0	0.00	0.00	25.00	S'bosrand
140	Sombre Greenbul	1	25.00	0.30	0	0.00	0.00	25.00	S'bosrand
141	Southern Black Flycatcher	1	25.00	0.30	0	0.00	0.00	25.00	S'bosrand
142	Southern White-faced Scops-Owl	1	25.00	0.59	0	0.00	0.00	25.00	S'bosrand
143	Tinkling Cisticola	1	25.00	0.59	0	0.00	0.00	25.00	S'bosrand
144	Violet Wood-Hoopoe	1	25.00	0.59	0	0.00	0.00	25.00	S'bosrand
145	White-browed Robin-Chat	1	25.00	0.72	0	0.00	0.00	25.00	S'bosrand
146	Wire-tailed Swallow	1	25.00	0.72	0	0.00	0.00	25.00	S'bosrand
147	Yellow-collared Lovebird	1	25.00	0.59	0	0.00	0.00	25.00	S'bosrand
148	African Red-eyed Bulbul	4	100.00	70.38	25	78.13	16.67	21.88	indifferent
149	Mountain Wheatear	4	100.00	74.50	25	78.13	15.38	21.88	indifferent
150	Cardinal Woodpecker	3	75.00	8.16	17	53.13	7.69	21.88	indifferent
151	African Marsh-Harrier	2	50.00	2.67	9	28.13	4.76	21.88	indifferent
152	Brown-backed Honeybird	2	50.00	4.94	9	28.13	7.69	21.88	indifferent
153	Long-tailed Paradise-Whydah	2	50.00	1.34	9	28.13	6.12	21.88	indifferent
154	Black Cuckoo	1	25.00	0.30	1	3.13	0.75	21.88	indifferent
155	Black Harrier	1	25.00	1.44	1	3.13	0.42	21.88	indifferent
156	Black-crowned Tchagra	1	25.00	0.30	1	3.13	0.50	21.88	indifferent
157	Black-winged Lapwing	1	25.00	0.30	1	3.13	0.25	21.88	indifferent
158	Blue Korhaan	1	25.00	0.30	1	3.13	6.90	21.88	indifferent
159	Brown Snake-Eagle	1	25.00	4.08	1	3.13	0.25	21.88	indifferent
160	Crested Guineafowl	1	25.00	0.30	1	3.13	2.22	21.88	indifferent
161	Eurasian Hobby	1	25.00	0.59	1	3.13	0.75	21.88	indifferent
162	Fiery-necked Nightjar	1	25.00	0.59	1	3.13	2.02	21.88	indifferent
163	Long-tailed Pipit	1	25.00	0.59	1	3.13	0.50	21.88	indifferent
164	Natal Spurfowl	1	25.00	0.30	1	3.13	0.75	21.88	indifferent

165	Pale Flycatcher	1	25.00	0.30	1	3.13	2.00	21.88	indifferent
166	Purple Indigobird	1	25.00	1.18	1	3.13	8.23	21.88	indifferent
167	Southern Yellow-billed Hornbill	1	25.00	0.30	1	3.13	1.75	21.88	indifferent
168	Striped Pipit	1	25.00	1.18	1	3.13	1.75	21.88	indifferent
169	African Black Duck	4	100.00	2.65	26	81.25	15.79	18.75	indifferent
170	Bar-throated Apalis	3	75.00	26.04	18	56.25	8.00	18.75	indifferent
171	Common Greenshank	3	75.00	3.32	18	56.25	7.69	18.75	indifferent
172	African Rail	2	50.00	0.51	10	31.25	11.15	18.75	indifferent
173	Black-crowned Night-Heron	2	50.00	0.66	10	31.25	11.31	18.75	indifferent
174	Blue Waxbill	2	50.00	0.89	10	31.25	4.70	18.75	indifferent
175	Cape Teal	2	50.00	2.40	10	31.25	13.57	18.75	indifferent
176	Abdim's Stork	1	25.00	0.30	2	6.25	0.63	18.75	indifferent
177	African Crake	1	25.00	0.30	2	6.25	2.81	18.75	indifferent
178	African Grey Hornbill	1	25.00	0.30	2	6.25	0.63	18.75	indifferent
179	Booted Eagle	1	25.00	2.04	2	6.25	2.94	18.75	indifferent
180	Bush Blackcap	1	25.00	1.51	2	6.25	3.85	18.75	indifferent
181	Corn Crake	1	25.00	0.30	2	6.25	1.13	18.75	indifferent
182	Temminck's Courser	1	25.00	0.30	2	6.25	0.54	18.75	indifferent
183	Violet-backed Starling	1	25.00	1.78	2	6.25	6.62	18.75	indifferent
184	Lesser Swamp-Warbler	4	100.00	4.86	27	84.38	33.33	15.63	indifferent
185	Neddicky Neddicky	4	100.00	38.31	27	84.38	37.93	15.63	indifferent
186	Northern Black Korhaan	4	100.00	24.10	27	84.38	31.43	15.63	indifferent
187	Steppe Buzzard	4	100.00	13.72	27	84.38	10.34	15.63	indifferent
188	Yellow Canary	4	100.00	33.39	27	84.38	16.67	15.63	indifferent
189	European Roller	1	25.00	0.30	3	9.38	2.00	15.63	indifferent
190	Shikra	1	25.00	0.30	3	9.38	1.75	15.63	indifferent
191	Violet-eared Waxbill	1	25.00	3.55	3	9.38	7.69	15.63	indifferent
192	Yellow-throated Petronia	1	25.00	0.30	3	9.38	4.00	15.63	indifferent
193	Bokmakierie	4	100.00	59.86	28	87.50	34.07	12.50	indifferent

194	Common Moorhen	4	100.00	11.97	28	87.50	32.57	12.50	indifferent
195	Red-collared Widowbird	4	100.00	49.10	28	87.50	24.72	12.50	indifferent
196	Tawny-flanked Prinia	4	100.00	14.87	28	87.50	16.52	12.50	indifferent
197	Acacia Pied Barbet	3	75.00	42.90	20	62.50	15.27	12.50	indifferent
198	Squacco Heron	3	75.00	1.44	20	62.50	7.55	12.50	indifferent
199	Common Ostrich	2	50.00	0.45	12	37.50	17.22	12.50	indifferent
200	Greater Honeyguide	2	50.00	2.08	12	37.50	6.47	12.50	indifferent
201	Marsh Sandpiper	2	50.00	0.51	12	37.50	6.39	12.50	indifferent
202	African Firefinch	1	25.00	0.59	4	12.50	1.39	12.50	indifferent
203	African Jacana	1	25.00	0.60	4	12.50	6.97	12.50	indifferent
204	Chestnut-backed Sparrowlark	1	25.00	0.72	4	12.50	8.01	12.50	indifferent
205	Crimson-breasted Shrike	1	25.00	0.30	4	12.50	9.90	12.50	indifferent
206	Pink-billed Lark	1	25.00	10.79	4	12.50	9.73	12.50	indifferent
207	Sedge Warbler	1	25.00	0.30	4	12.50	2.76	12.50	indifferent
208	Swallow-tailed Bee-eater	1	25.00	1.78	4	12.50	2.03	12.50	indifferent
209	Village Indigobird	1	25.00	0.59	4	12.50	4.30	12.50	indifferent
210	Yellow-billed Stork	1	25.00	0.30	4	12.50	6.09	12.50	indifferent
211	African Palm-Swift	4	100.00	2.82	29	90.63	31.03	9.38	indifferent
212	African Snipe	4	100.00	19.23	29	90.63	15.38	9.38	indifferent
213	Fiscal Flycatcher	4	100.00	64.18	29	90.63	30.77	9.38	indifferent
214	South African Cliff-Swallow	4	100.00	10.12	29	90.63	21.05	9.38	indifferent
215	Spike-heeled Lark	4	100.00	13.19	29	90.63	11.54	9.38	indifferent
216	Spotted Thick-knee	4	100.00	5.97	29	90.63	18.00	9.38	indifferent
217	White-browed Sparrow-Weaver	4	100.00	43.52	29	90.63	64.00	9.38	indifferent
218	White-winged Widowbird	4	100.00	13.65	29	90.63	17.65	9.38	indifferent
219	Malachite Kingfisher	3	75.00	3.93	21	65.63	7.69	9.38	indifferent
220	Black-winged Pratincole	2	50.00	2.76	13	40.63	3.45	9.38	indifferent
221	Black-necked Grebe	1	25.00	0.30	5	15.63	8.33	9.38	indifferent

222	Jameson's Firefinch	1	25.00	3.55	5	15.63	4.04	9.38	indifferent
223	Village Weaver	1	25.00	0.60	5	15.63	3.85	9.38	indifferent
224	African Quailfinch	4	100.00	13.49	30	93.75	18.22	6.25	indifferent
225	Anteating Chat	4	100.00	67.39	30	93.75	27.60	6.25	indifferent
226	Capped Wheatear	4	100.00	38.65	30	93.75	27.18	6.25	indifferent
227	Green Wood-Hoopoe	4	100.00	13.34	30	93.75	22.14	6.25	indifferent
228	Pied Starling	4	100.00	5.67	30	93.75	30.20	6.25	indifferent
229	Red-capped Lark	4	100.00	10.88	30	93.75	21.88	6.25	indifferent
230	Red-headed Finch	4	100.00	2.62	30	93.75	15.38	6.25	indifferent
231	Red-throated Wryneck	4	100.00	42.07	30	93.75	16.52	6.25	indifferent
232	Speckled Mousebird	4	100.00	19.11	30	93.75	30.09	6.25	indifferent
233	Pied Kingfisher	3	75.00	2.16	22	68.75	7.61	6.25	indifferent
234	Willow Warbler	3	75.00	8.76	22	68.75	9.57	6.25	indifferent
235	South African Shelduck	2	50.00	1.74	14	43.75	8.13	6.25	indifferent
236	Black-headed Oriole	1	25.00	1.21	6	18.75	3.78	6.25	indifferent
237	Pearl-breasted Swallow	1	25.00	0.30	6	18.75	2.85	6.25	indifferent
238	African Darter	4	100.00	5.52	31	96.88	16.67	3.13	indifferent
239	African Hoopoe	4	100.00	37.39	31	96.88	23.08	3.13	indifferent
240	Black-collared Barbet	4	100.00	41.02	31	96.88	35.29	3.13	indifferent
241	Cape Robin-Chat	4	100.00	66.31	31	96.88	52.94	3.13	indifferent
242	Cape White-eye	4	100.00	50.77	31	96.88	44.44	3.13	indifferent
243	Cloud Cisticola	4	100.00	22.25	31	96.88	30.77	3.13	indifferent
244	Common Waxbill	4	100.00	24.06	31	96.88	25.00	3.13	indifferent
245	Crested Barbet	4	100.00	56.25	31	96.88	53.85	3.13	indifferent
246	Dark-capped Bulbul	4	100.00	23.03	31	96.88	52.94	3.13	indifferent
247	Red-billed Teal	4	100.00	7.36	31	96.88	30.54	3.13	indifferent
248	Rock Dove	4	100.00	7.98	31	96.88	26.92	3.13	indifferent
249	Rufous-naped Lark	4	100.00	46.52	31	96.88	38.46	3.13	indifferent
250	Southern Grey-headed Sparrow	4	100.00	29.39	31	96.88	28.57	3.13	indifferent

251	Three-banded Plover	4	100.00	10.56	31	96.88	30.77	3.13	indifferent
252	Wattled Starling	4	100.00	4.20	31	96.88	17.65	3.13	indifferent
253	White-breasted Cormorant	4	100.00	3.31	31	96.88	14.29	3.13	indifferent
254	Hamerkop Hamerkop	3	75.00	5.76	23	71.88	5.56	3.13	indifferent
255	Yellow-billed Egret	3	75.00	2.16	23	71.88	7.69	3.13	indifferent
256	Ruff	2	50.00	0.96	15	46.88	14.29	3.13	indifferent
257	Black-faced Waxbill	1	25.00	3.55	7	21.88	4.76	3.13	indifferent
258	Little Sparrowhawk	1	25.00	0.30	7	21.88	1.27	3.13	indifferent
259	African Pipit	4	100.00	23.42	32	100.00	58.48	0.00	Generalist
260	African Sacred Ibis	4	100.00	16.13	32	100.00	36.28	0.00	Generalist
261	African Stonechat	4	100.00	88.06	32	100.00	84.52	0.00	Generalist
262	African Wattled Lapwing	4	100.00	7.63	32	100.00	19.72	0.00	Generalist
263	Amur Falcon	4	100.00	24.67	32	100.00	24.72	0.00	Generalist
264	Barn Swallow	4	100.00	38.83	32	100.00	50.25	0.00	Generalist
265	Black-chested Prinia	4	100.00	38.72	32	100.00	52.79	0.00	Generalist
266	Black-headed Heron	4	100.00	18.70	32	100.00	52.06	0.00	Generalist
267	Black-shouldered Kite	4	100.00	54.92	32	100.00	66.67	0.00	Generalist
268	Blacksmith Lapwing	4	100.00	64.90	32	100.00	92.45	0.00	Generalist
269	Black-throated Canary	4	100.00	40.27	32	100.00	69.23	0.00	Generalist
270	Brown-throated Martin	4	100.00	16.14	32	100.00	36.28	0.00	Generalist
271	Cape Glossy Starling	4	100.00	24.57	32	100.00	53.11	0.00	Generalist
272	Cape Longclaw	4	100.00	78.69	32	100.00	74.67	0.00	Generalist
273	Cape Sparrow	4	100.00	34.56	32	100.00	94.00	0.00	Generalist
274	Cape Turtle-Dove	4	100.00	73.02	32	100.00	94.70	0.00	Generalist
275	Cape Wagtail	4	100.00	38.20	32	100.00	64.21	0.00	Generalist
276	Cattle Egret	4	100.00	37.63	32	100.00	66.67	0.00	Generalist
277	Common Fiscal	4	100.00	65.59	32	100.00	94.06	0.00	Generalist
278	Common Myna	4	100.00	28.67	32	100.00	88.46	0.00	Generalist
279	Crowned Lapwing	4	100.00	44.39	32	100.00	88.07	0.00	Generalist

280	Diderick Cuckoo	4	100.00	31.49	32	100.00	26.97	0.00	Generalist
281	Egyptian Goose	4	100.00	22.48	32	100.00	69.74	0.00	Generalist
282	Glossy Ibis	4	100.00	16.17	32	100.00	32.96	0.00	Generalist
283	Greater Striped Swallow	4	100.00	34.31	32	100.00	58.23	0.00	Generalist
284	Grey Heron	4	100.00	8.11	32	100.00	24.87	0.00	Generalist
285	Hadeda Ibis	4	100.00	34.38	32	100.00	88.56	0.00	Generalist
286	Helmeted Guineafowl	4	100.00	46.31	32	100.00	70.33	0.00	Generalist
287	House Sparrow	4	100.00	13.68	32	100.00	47.26	0.00	Generalist
288	Laughing Dove	4	100.00	77.26	32	100.00	97.87	0.00	Generalist
289	Levaillant's Cisticola	4	100.00	79.71	32	100.00	72.87	0.00	Generalist
290	Little Grebe	4	100.00	32.03	32	100.00	38.46	0.00	Generalist
291	Little Swift	4	100.00	22.14	32	100.00	31.50	0.00	Generalist
292	Long-tailed Widowbird	4	100.00	74.72	32	100.00	85.16	0.00	Generalist
293	Pin-tailed Whydah	4	100.00	38.77	32	100.00	47.17	0.00	Generalist
294	Red-billed Quelea	4	100.00	16.06	32	100.00	37.47	0.00	Generalist
295	Red-eyed Dove	4	100.00	38.56	32	100.00	77.35	0.00	Generalist
296	Red-faced Mousebird	4	100.00	34.01	32	100.00	40.69	0.00	Generalist
297	Red-knobbed Coot	4	100.00	46.54	32	100.00	68.66	0.00	Generalist
298	Reed Cormorant	4	100.00	34.01	32	100.00	51.53	0.00	Generalist
299	Southern Masked-Weaver	4	100.00	84.79	32	100.00	94.43	0.00	Generalist
300	Southern Red Bishop	4	100.00	55.00	32	100.00	75.74	0.00	Generalist
301	Speckled Pigeon	4	100.00	40.43	32	100.00	75.43	0.00	Generalist
302	Spur-winged Goose	4	100.00	18.98	32	100.00	32.18	0.00	Generalist
303	Swainson's Spurfowl	4	100.00	50.05	32	100.00	50.00	0.00	Generalist
304	White-faced Duck	4	100.00	7.52	32	100.00	23.08	0.00	Generalist
305	White-rumped Swift	4	100.00	30.07	32	100.00	47.42	0.00	Generalist
306	White-throated Swallow	4	100.00	25.84	32	100.00	44.10	0.00	Generalist
307	Yellow-billed Duck	4	100.00	57.27	32	100.00	58.26	0.00	Generalist
308	Yellow-crowned Bishop	4	100.00	20.51	32	100.00	32.04	0.00	Generalist

309	Zitting Cisticola	4	100.00	30.64	32	100.00	41.18	0.00	Generalist
310	Orange River Francolin	3	75.00	13.90	24	75.00	11.15	0.00	indifferent
311	Bronze Mannikin	1	25.00	0.60	8	25.00	3.65	0.00	indifferent
312	Ovambo Sparrowhawk	1	25.00	2.04	8	25.00	5.15	0.00	indifferent
313	Spotted Flycatcher	3	75.00	10.88	25	78.13	7.69	–3.13	indifferent
314	Fulvous Duck	2	50.00	2.19	17	53.13	8.89	–3.13	indifferent
315	Common Swift	1	25.00	0.91	9	28.13	5.88	–3.13	indifferent
316	African Broadbill	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
317	African Green-Pigeon	0	0.00	0.00	1	3.13	3.77	–3.13	indifferent
318	African Hawk-Eagle	0	0.00	0.00	1	3.13	0.50	–3.13	indifferent
319	African Openbill	0	0.00	0.00	1	3.13	5.26	–3.13	indifferent
320	African Scops-Owl	0	0.00	0.00	1	3.13	0.50	–3.13	indifferent
321	Baillon's Crake	0	0.00	0.00	1	3.13	0.42	–3.13	indifferent
322	Bronze-winged Courser	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
323	Bushveld Pipit	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
324	Cape Batis	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
325	Cape Bulbul	0	0.00	0.00	1	3.13	0.50	–3.13	indifferent
326	Cape Cormorant	0	0.00	0.00	1	3.13	0.63	–3.13	indifferent
327	Chirinda Apalis	0	0.00	0.00	1	3.13	2.22	–3.13	indifferent
328	Comb Duck	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
329	Common Whitethroat	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
330	Coqui Francolin	0	0.00	0.00	1	3.13	0.63	–3.13	indifferent
331	Dusky Indigobird	0	0.00	0.00	1	3.13	0.50	–3.13	indifferent
332	Emerald-spotted Wood-Dove	0	0.00	0.00	1	3.13	4.76	–3.13	indifferent
333	Greater Painted-snipe	0	0.00	0.00	1	3.13	3.77	–3.13	indifferent
334	House Crow	0	0.00	0.00	1	3.13	1.01	–3.13	indifferent
335	Karoo Scrub-Robin	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
336	Little Bee-eater	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
337	Martial Eagle	0	0.00	0.00	1	3.13	3.85	–3.13	indifferent

338	Meyer's Parrot	0	0.00	0.00	1	3.13	14.81	–3.13	indifferent
339	Olive-tree Warbler	0	0.00	0.00	1	3.13	0.75	–3.13	indifferent
340	Pearl-spotted Owlet	0	0.00	0.00	1	3.13	5.26	–3.13	indifferent
341	Red-billed Buffalo-Weaver	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
342	Red-breasted Swallow	0	0.00	0.00	1	3.13	0.84	–3.13	indifferent
343	Red-headed Quelea	0	0.00	0.00	1	3.13	0.50	–3.13	indifferent
344	Retz's Helmet-Shrike	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
345	Scaly-feathered Finch	0	0.00	0.00	1	3.13	3.85	–3.13	indifferent
346	Southern Black Korhaan	0	0.00	0.00	1	3.13	7.69	–3.13	indifferent
347	Southern Black Tit	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
348	Southern Brown-throated Weaver	0	0.00	0.00	1	3.13	7.69	–3.13	indifferent
349	Three-banded Courser	0	0.00	0.00	1	3.13	7.69	–3.13	indifferent
350	Wahlberg's Eagle	0	0.00	0.00	1	3.13	0.50	–3.13	indifferent
351	Water Thick-knee	0	0.00	0.00	1	3.13	5.56	–3.13	indifferent
352	Western Marsh-Harrier	0	0.00	0.00	1	3.13	0.42	–3.13	indifferent
353	White-crested Helmet-Shrike	0	0.00	0.00	1	3.13	2.78	–3.13	indifferent
354	White-tailed Crested Flycatcher	0	0.00	0.00	1	3.13	0.25	–3.13	indifferent
355	Yellow Wagtail	0	0.00	0.00	1	3.13	3.85	–3.13	indifferent
356	Cape Shoveler	3	75.00	3.02	26	81.25	16.03	–6.25	indifferent
357	African Purple Swamphen	2	50.00	1.23	18	56.25	9.34	–6.25	indifferent
358	Black Crake	2	50.00	7.26	18	56.25	6.19	–6.25	indifferent
359	Goliath Heron	2	50.00	3.80	18	56.25	6.17	–6.25	indifferent
360	Pied Avocet	2	50.00	0.81	18	56.25	7.82	–6.25	indifferent
361	White-winged Tern	2	50.00	2.19	18	56.25	7.55	–6.25	indifferent
362	Green-backed Heron	1	25.00	0.60	10	31.25	5.24	–6.25	indifferent
363	Little Bittern	1	25.00	3.02	10	31.25	4.63	–6.25	indifferent
364	Mallard Duck	1	25.00	0.91	10	31.25	8.27	–6.25	indifferent

365	Black Stork	0	0.00	0.00	2	6.25	7.64	–6.25	indifferent
366	Caspian Tern	0	0.00	0.00	2	6.25	2.80	–6.25	indifferent
367	Common Starling	0	0.00	0.00	2	6.25	1.93	–6.25	indifferent
368	Freckled Nightjar	0	0.00	0.00	2	6.25	3.28	–6.25	indifferent
369	Half-collared Kingfisher	0	0.00	0.00	2	6.25	0.44	–6.25	indifferent
370	Harlequin Quail	0	0.00	0.00	2	6.25	0.33	–6.25	indifferent
371	Icterine Warbler	0	0.00	0.00	2	6.25	2.13	–6.25	indifferent
372	Southern Bald Ibis	0	0.00	0.00	2	6.25	4.67	–6.25	indifferent
373	Yellow-fronted Tinkerbird	0	0.00	0.00	2	6.25	0.63	–6.25	indifferent
374	African Olive-Pigeon	1	25.00	0.30	11	34.38	14.29	–9.38	indifferent
375	Common Ringed Plover	0	0.00	0.00	3	9.38	3.85	–9.38	indifferent
376	Grey-backed Sparrowlark	0	0.00	0.00	3	9.38	2.86	–9.38	indifferent
377	Orange River White-eye	0	0.00	0.00	3	9.38	2.00	–9.38	indifferent
378	Red-billed Firefinch	0	0.00	0.00	3	9.38	0.63	–9.38	indifferent
379	Rose-ringed Parakeet	0	0.00	0.00	3	9.38	0.84	–9.38	indifferent
380	White-throated Bee-eater	0	0.00	0.00	3	9.38	2.00	–9.38	indifferent
381	Woodland Kingfisher	0	0.00	0.00	3	9.38	3.70	–9.38	indifferent
382	Black Heron	1	25.00	2.16	12	37.50	6.64	–12.50	indifferent
383	Great Crested Grebe	1	25.00	3.63	12	37.50	8.93	–12.50	indifferent
384	White-fronted Bee-eater	1	25.00	2.96	12	37.50	10.17	–12.50	indifferent
385	Black Kite	0	0.00	0.00	4	12.50	0.53	–12.50	indifferent
386	Greater Double-collared Sunbird	0	0.00	0.00	4	12.50	1.89	–12.50	indifferent
387	Rufous-cheeked Nightjar	0	0.00	0.00	4	12.50	6.27	–12.50	indifferent
388	Shaft-tailed Whydah	0	0.00	0.00	4	12.50	3.96	–12.50	indifferent
389	Karoo Thrush	3	75.00	30.82	29	90.63	27.78	–15.63	indifferent
390	Wood Sandpiper	2	50.00	2.76	21	65.63	7.69	–15.63	indifferent
391	Peregrine Falcon	0	0.00	0.00	5	15.63	2.78	–15.63	indifferent
392	Common Peacock	0	0.00	0.00	6	18.75	6.79	–18.75	indifferent
393	Long-crested Eagle	0	0.00	0.00	6	18.75	5.80	–18.75	indifferent

394	Grey-headed Gull	2	50.00	7.95	23	71.88	15.90	–21.88	indifferent
395	Southern Pochard	2	50.00	7.42	23	71.88	12.50	–21.88	indifferent
396	Grey Go-away-bird	1	25.00	0.60	15	46.88	13.13	–21.88	indifferent
397	Black-winged Stilt	2	50.00	8.14	24	75.00	15.98	–25.00	Outside
398	Little Stint	1	25.00	0.72	16	50.00	10.44	–25.00	Outside
399	Lesser Flamingo	0	0.00	0.00	8	25.00	5.89	–25.00	Outside
400	Namaqua Dove	2	50.00	2.10	25	78.13	6.12	–28.13	Outside
401	Hottentot Teal	1	25.00	0.30	17	53.13	7.69	–28.13	Outside
402	Curlew Sandpiper	0	0.00	0.00	9	28.13	7.14	–28.13	Outside
403	Giant Kingfisher	1	25.00	0.59	18	56.25	7.18	–31.25	Outside
404	Kittlitz's Plover	0	0.00	0.00	10	31.25	7.29	–31.25	Outside
405	Little Rush-Warbler	1	25.00	4.53	19	59.38	7.69	–34.38	Outside
406	African Spoonbill	2	50.00	8.47	29	90.63	11.43	–40.63	Outside
407	Whiskered Tern	2	50.00	13.12	29	90.63	8.89	–40.63	Outside
408	Little Egret	2	50.00	8.32	30	93.75	15.38	–43.75	Outside
409	Greater Flamingo	0	0.00	0.00	19	59.38	11.11	–59.38	Outside

Chapter Five

Spatial distribution patterns of avian species diversity in Greater Gauteng, South Africa

Abstract

Approximately 30% of South Africa's population lives in Greater Gauteng. The impact of urban development has been continuous through more than a century. Natural vegetation is steadily being replaced with urban structures. One manifestation of exponential human population growth has been unplanned expansion of human settlements, known as squatter camps. At the other extreme are some of the wealthiest neighbourhoods in Africa. The synergy of the impacts of all these factors must have influenced the spatial distribution patterns of birds in this region. The Shannon Diversity Index was adapted for use with bird atlas data two decades ago and was successfully used to assess spatial patterns of bird distributions. This chapter uses the modified diversity index to describe patterns of distribution of bird diversity in Greater Gauteng. Over Greater Gauteng as a whole, diversity was larger in the savanna biome to the north than in the grassland biome to the south, Invasive species were occurred mainly in the urban and suburban areas of Johannesburg and Pretoria. Throughout Greater Gauteng, the largest diversity of threatened species was focused on the Devan Grasslands Important Bird Area. Waterbird diversity wasn largest in the south-eastern part of the study area. This diversity index has broad applications; for example, it can be used for site selection for biodiversity conservation.

Introduction

This chapter is about birds in cities and the rural areas just outside cities of Greater Gauteng, South Africa. Twenty-five percent of South Africa's population lives in the province of Gauteng, South Africa; the cities of Johannesburg and Pretoria are the economic powerhouses of the country, if not the continent. Greater Gauteng consists of four one-degree grid cells centred on the province of Gauteng, including peripheral towns in the neighbouring provinces of North West, Limpopo, Mpumalanga and Free State (Fig. 1.1). The study area is home to about 30% of South Africa's human population. Greater Gauteng is the most rapidly urbanizing, wealthy and populated area in South Africa, where development pressure is greatest (Ainsley, 2016, Underhill and Brooks, 2016). Some of the resultant effects of urbanization and its impacts on the environment include fragmentation, modification and transformation of natural habitats which have been replaced by urban structures such as roads, buildings and all the other infrastructure associated with urban environments (Gaston, 2010). Human population growth in urban areas is compounded by influxes of people from rural to urban areas, driven mostly by economic factors (Gaston et al., 2010). This influx usually results in unplanned expansion of human settlements especially on the periphery of urban areas. This is also true of the situation in Greater Gauteng (Marnewick et al., 2015, Ainsley, 2016. Ainsley *pers. comm.*). These urbanization factors impact the environment, which cascade to transform the biodiversity in the resulting fragmented and transformed habitats (McKinney, 2010). The resultant effect of these factors on biodiversity is of concern to conservation biologists, hence the increasing need for research in urban ecology to understand the spatial and temporal response of biodiversity to these drivers of urbanization.

The field of urban ecology is relatively new especially in the tropics where our knowledge of the current state of urban biodiversity is limited. (Chuan Lim and Sodhi, 2004, Chase and Walsh, 2006, McKinney, 2008, Gaston, 2010, Leveau and Leveau, 2012). It has, however, been documented that declines in biodiversity and increasing urbanization are strongly correlated (McKinney, 2002; Thompson et al., 2003; Pauchard, et al., 2006; Nature Conservancy, 2008, Ahrne et al., 2009). Understanding the state of biodiversity in any given area is inherently tied to the availability of species data. The Second Southern African Bird Atlas Project (SABAP2) is a citizen science project which has generated large volumes of data relating to the presence and absence of bird species in Greater Gauteng (Ainsley, 2016). However, bird data alone are limited in how much information we can derive from them on the status of bird biodiversity. This highlights the need for a measure of species diversity which is more informative. One of the most commonly used measures of species diversity is the Shannon Index (Spellerberg and Fedor, 2003). Species diversity is commonly used for assessing patterns and processes of biodiversity at both ecological and biogeographic scales (Harrison and Martinez, 1995, Underhill et al., 1998, Chiarucci et al., 2011). It has also been shown to have a strong positive correlation with diversity at other levels of organization, such as genetic diversity and ecosystem functioning (Colwell and Coddington, 1994).

In this chapter, I use bird atlas data for Greater Gauteng to investigate the spatial distribution patterns of avian biodiversity in the area. I make use of the same species diversity index as originally developed by Harrison and Martinez (1995), and a strategy for decomposing this index into the contributions of groups of species to the index, developed by Underhill et al. (1998). Both Harrison and Martinez (1995) and Underhill et al. (1998) demonstrated that this species diversity index provided valuable insights into patterns within species communities even though it was based on the presence-absence data generated by the bird atlas, rather than on actual counts of population sizes of species. This chapter uses these methods to address the following questions: (i) Can SABAP2 atlas data provide information on the spatial distribution of the bird diversity in Greater Gauteng? (ii) Which groups of bird species contribute large proportions to the overall bird diversity in Greater Gauteng? (iii) Which areas and habitats hold the largest bird species diversity in Greater Gauteng?

Materials and Methods

Study Area

Greater Gauteng (Fig. 1.1) is an area centred on the Gauteng province of South Africa. It has made up of four one-degree grid cells. For ease of description, the four grids are named by the latitude and longitude of their northwest corner, and their positions relative to each other. The four one-degree grid cells that make up the area are; 25S 27E ("northwest"), 25S 28E ("northeast"), 26S 27E ("southwest") and 26S 28E ("southeast"). The Second Southern African Bird Atlas Project uses a five-minute grid; there are therefore 12 rows and 12 columns of atlas grid cells per one-degree grid cell, or 144 atlas cells, known as pentads. The whole area thus contains 576 pentads, 270 of which fall mainly in Gauteng (Ainsley, 2016).

Habitat

The study area is covered by two main types of habitat biomes, these are the Savanna and Grassland habitats. The spatial distribution of the habitat types almost cuts through the middle of the study area dividing the area into two near equal parts along the 26°S latitude line with the Savanna habitat dominating the two-degree grid cells north of 26°S and Grassland habitat dominating the two-degree grid cells south of 26°S (Rutherford and Westfall, 1994, 1996, Allan et al., 1997).

The Savanna biome is the largest in southern Africa; it is characterized by a vegetation of grassy ground layer and an upper layer of woody plants often referred to as woodland. The major environmental delimiting factors of the Savanna biome includes altitude and rainfall (Allan et al., 1997). Savannas occur in altitude ranging from sea level to 2000 m above sea level. The average rainfall in this biome ranges from 234 to 1000 mm per year (Rutherford and Westfall, 1994, Rutherford et al., 2006).

The Grassland biome occurs mainly on high areas of the central plateau of South Africa as well as inland areas of KwaZulu-Natal and Eastern Cape. The landscape is characterized by rolling flat escarpments. Trees are usually absent in grasslands except for a few localized stands. The vegetation is dominated by a single layer of grasses with varying levels of cover dependent on the amount of rainfall which ranges between 430mm and 625 mm per year (Allan et al., 1997). Grasslands occur in altitude ranging from near sea level to about 2850 m above sea level. In terms of plant species richness in the region, the Grassland biome is second to the Fynbos biome (Rutherford and Westfall, 1994, Allan et al., 1997).

Data analysis

Data were generated from the bird checklists in the database of the Second Southern African Bird Atlas Project (SABAP2) for the study area. Checklists submitted between June 2007 to August 2016 were used for this analysis. Data were collected at the spatial unit of a pentad as per the SABAP2 fieldwork protocol (Harrison and Underhill 1997, Underhill et al. 2017). A pentad measures five minutes of latitude (c. 9.2 km) by five minutes of longitude (c. 8.2 km) (Underhill and Brooks, 2016).

Greater Gauteng has the most intensive SABAP2 fieldwork in South Africa, with the 576 pentads within the study area each having at least 11 checklists by June 2016 (Ainsley, 2016, Underhill and Brooks, 2016). This enables the study area to be a model for developing the statistical methods to monitor changes and patterns in diversity, distribution and abundance of bird species.

I used the modified Shannon-Weiner diversity index developed by Harrison and Martinez (1995) to calculate diversity indices for all species, and a method devised by Underhill et al. (1998) to calculate the proportional contribution to the total or overall species diversity of groups of species ("proportional diversity index") within a pentad. With the calculated indices, I generated plots which showed the spatial pattern of distribution of the species diversity in Greater Gauteng, and for various groups of species.

Selecting subgroups of species

I considered four sub-groups of species for the analysis. The subgroups are: non-native or Invasive species, Urban species, Threatened species and Waterbirds. I select these four categories for their conservation and ecological importance which is central to the theme of this thesis. The Invasive species are species that do not originally occur in a specified area but were imported by humans (McKinney and Lockwood, 1999). These species in most instances become pests and better competitors to the native species (Bertin 2002). Studies have also shown that the invasive species tend to increase in abundance in and around urban areas (Marzluff, 2001). In this chapter, I refer birds that fall in this category as the invasive or non-native sub-group. Admittedly, the characteristics of invasive and urban species are similar and may overlap. The only differentiating factor I used in this chapter is species that were categorized in the urban sub-group are those that occurred more in urban pentads than rural pentads of Greater Gauteng (Chapter 2). Threatened species are species listed by IUCN as facing extinction threat either regionally or globally (Marnewick et al., 2015, Taylor et al., 2015). In this chapter, the birds that I categorized in the sub-group of being Threatened are species that are faced with the various degree of extinction threats at the regional level of their distribution. Finally, waterbirds are bird species which depend on or utilize inland waterbodies (Kirby et al., 2008, Green and Elmberg 2013). Results have shown a high richness and abundance of waterbirds in Greater Gauteng (Chapter One and Two). I therefore, included them as a sub-group to investigate the proportional diversity index waterbirds contribute to the overall species diversity index of Greater Gauteng.

Proportional diversity index (P_G) for subgroup of species

I calculated and plotted the proportional diversity index (P_G) for sub-groups of species. This measure gives us the relative contribution of the species diversity that the sub-group contributes to the absolute species diversity (H) of the total or overall species. This is calculated at pentad level. A pentad with more species richness will have a higher overall species diversity score (H) than a pentad with less species richness. The proportional diversity index (P_G) however, measures the relative contribution that a subset of species in the pentad give to the overall species diversity (H) in the pentad. The scores can then be presented in a spatial plot where pentads with higher species diversity (H or P_G) will appear as comparatively bigger dots. The results for the H and P_G of all the sub-groups of species is presented in such spatially explicit plots.

Results

The modified Shannon-Weaver diversity index suggests that the northeast and northwest one-degree grid cells have a larger overall diversity (H_G) than the southeast and southwest grid cells (Fig. 5.2). This spatial pattern of the total species diversity index displays a distinctive boundary along the latitude 26°S line; with the two grid-cells north of the latitudinal line showing higher species diversity than the two one-degree grid cells to the south. In the study area, the boundary between the Savanna and Grassland biomes is remarkably close to latitude 26°S. The spatial pattern of species diversity shows higher species diversity in the savanna habitats as compared to the grassland habitats (Fig. 5.2).

Proportional diversity index (P_G) for sub-group of species

The spatial pattern of distribution for the proportional diversity index (P_G) contributed by the urban species to overall species diversity(H) in Greater Gauteng (Fig.5.3), showed the urban species contributed the largest proportional species diversity index in the central areas of Johannesburg and Pretoria municipalities and neighbouring areas of Greater Gauteng. It also shows patterns of high urban species proportional diversity in peripheral areas of Greater Gauteng (Fig. 5.3).

The spatial pattern of distribution for the proportional diversity index (P_G) contributed by the sub-group of non-native or invasive to the overall species diversity(H) in Greater Gauteng (Fig. 5.4) showed a similar pattern to the proportional diversity index contributed by urban species to the overall species diversity index (H). The spatial pattern reveals large proportional diversity in the central areas of Johannesburg and Pretoria municipalities and neighbouring areas of Greater Gauteng (Fig. 5.4).

The spatial pattern of distribution for the proportional diversity index (P_G) contributed by the sub-group of threatened species to the overall species diversity(H) of Greater Gauteng (Fig. 5.5), shows threatened species generally contribute little proportional species diversity index to the overall species diversity index (H) of Greater Gauteng. The area where the proportional diversity index (P_G) of threatened species showed a pattern of large contribution to total species diversity is in the southeast grid cell (Fig. 5.5).

The spatial pattern of distribution for the proportional diversity index (P_G) contributed by the sub-group of waterbird species to the overall species diversity(H) of Greater Gauteng (Fig. 5.5), showed large values for the waterbird proportional diversity index (P_G) in the south-east grid cell compared to the other three grid cells of Greater Gauteng (Fig. 5.6).

Discussion

Greater Gauteng is the most atlased SABAP2 region in South Africa, with all 576 pentads that is contained within the boundaries of Greater Gauteng having at least 11 checklists as at June 2016 (Ainsley, 2016, Underhill and Brooks, 2016). This has enabled Greater Gauteng to be a model for developing the algorithms to monitor changes and patterns in diversity, distribution and abundance of bird species in the area.

The methods used in this chapter focus on usage of species richness to describe the avian diversity of Greater Gauteng. Birds have been shown to be good bioindicators of the state of a habitat and its biodiversity (Temple and Weins, 1989, Bibby, 1999, Dmowski, 1999, Slowtow and Hamer, 2000, Duelli and Obrist, 2003). Given the choice of birds as bioindicators of the state of general biodiversity in the environment, the results of this research can be viewed as a reflection of the structural (the physical characteristics) and functional attributes (the ecological and evolutionary processes) of the state of biodiversity in Greater Gauteng. The area of Greater Gauteng with larger total avian species diversity could be an indication areas of higher biodiversity abundance and richness (Temple and Weins, 1989, Duelli and Obrist, 2003). I did not investigate the richness and abundance of other plants and animals due to absence of data. However, it will be interesting for future research to examine if the patterns of diversity and abundance of other plants and animals in the Greater Gauteng follows a similar pattern to that of the avifauna.

As more biodiversity increasingly face threats such as from climate change, increasing human population and urbanization, the need for biodiversity conservation also increases. However, as the need for biodiversity conservation increases, the resources available to meet these needs remains limited. This scenario warrants the need to apply some prioritization in conservation decisions for species (Ontoy and Padua, 2014). These decisions often depend on a measure of the biodiversity of the area. Several measures of biodiversity have been proposed and used with varying applications depending on the level and scale of diversity.

One of the most commonly used measures of biodiversity is the Shannon-Weiner Index (Spellerberg & Fedor, 2003), where species richness (i.e. number of species) and species abundance (i.e. number of individuals within the same species) are incorporated in the function. High Shannon-Index value (highly diverse areas) get prioritized for conservation. The Shannon index provides a solution for challenges encountered in comparing pentads with large differences in numbers of checklists. To avoid the distortions that result from such a comparisons, the index does provide a suitable indicator of the species diversity which quickly plateaus and remains stable after a reasonable small number of checklists (see figure 2 of Harrison and Martinez,1995) for a pentad is achieved and remains constant as the number of checklists increases and species richness steadily increasing (Harrison and Martinez, 1995, Underhill et al., 1998).

Harrison and Martinez (1995) showed that the modified Shannon diversity index can produce up to 93% and 96% asymptotic value of the diversity index of any grid cell with as little as five and 10 checklists, respectively. All of the 576 pentads in Greater Gauteng used in the analysis for this chapter have a minimum of 11 checklists. This gives an asymptotic value of 98% or higher for each pentad (see figure 2 of Harrison and Martinez,1995).

A weakness in the application of the Shannon-Weiner index is the inherent assumption that all species present in the area do not have additional values of importance other than numbers (Species richness and abundance). However, the reality states otherwise, for example, species that are endemic (or rare), of a Threatened status or keystone species (species which play important functions in the ecosystem) have additional importance value (Duelli and Obrist, 2003). It therefore, becomes important that these values should be incorporated when measuring indices for conservation of biodiversity. Underhill et al. (1998) used the modified Shannon-Weiner diversity index to compare diversity patterns between resident and migratory Palearctic insectivorous passerines in southern Africa. The Palearctic migrants concentrated in the thornbelt regions of Limpopo which also showed low densities of resident insectivorous passerines. Their results also showed that the core of the non-breeding distribution for the Palearctic insectivorous passerines is much smaller than had been previously reported.

This chapter uses the modified biodiversity index (Harrison and Martinez, 1995) to describe patterns of distribution of absolute and proportional diversity for the total and subgroups of avian biodiversity (Figs 5.1–5.5) in Greater Gauteng.

Total Species Diversity index

The pattern of overall or total species diversity distribution (Fig.5.2) in Greater Gauteng appears to reflect a pattern of two halves which splits along the latitude 26°S line. This boundary closely follows the vegetation biome distribution of the region (Allan et al., 1997). Greater Gauteng is dominated by two major habitat biomes; the Savanna woodland to the north of 26°S and Grassland to the south of 26°S. The interpretation of this spatial pattern of general species diversity can be understood in the context of the structural complexity of the habitats (Pianka and Huey, 1971, Allan et al., 1997). There is a general agreement for a positive correlation between bird diversity and the structural complexity of a habitat. This relationship between bird diversity and habitat structure has been demonstrated at regional scales of southern Africa (Pianka and Huey, 1971, Froneman et al., 2001) and various regions of the world (Tews et al., 2004, Erdelen, 1984, Weins and Rotenberry, 1981). Underhill et al. (1998) showed that the group diversity of resident and migrant insectivorous passerines reflects a pattern of the structural diversity of the habitats in southern Africa, with the woodlands and forests in areas of the region hosted the greatest diversity while the grassland, shrubland and arid areas of the region hosted least diversity.

Urban and invasive species

The pattern of urban and non-native or invasive species diversity concentrating around the more urban areas of Greater Gauteng is in consensus with previous research (McKinney, 2002, Klotz and Kuhn, 2010). These studies show that the urbanization in terms of expanding cities promote replacement of native species by non-native species or invasive species. For example, Bertin (2002), showed that for comparisons of plant inventories made at different times for 13 towns and cities representing several continents, native plant species richness declined between 3% and 46% in a span of 50–150 years while the proportion of urban species was on the increase. New York City has lost 578 native species (a loss of roughly 43% of the original native species) while gaining 411 non-native species in the last century (DeCandido et al., 2004). European and Australian cities show similar patterns of native species lost too (Chocholouskova and Pysek, 2003, Tait et al., 2005). This trend of increasing proportion of urban species toward the urban core has also been reported in birds (Marzluff, 2001), mammals (Mackin-Rogalska et al., 1988), and insects (McIntyre, 2000).

Urban population growth correlates positively with the size and intensity of urban land-use which alters the natural vegetation and landscape within and around the urban areas (Klotz and Kuhn, 2010). One consequence of this and other anthropogenic activities is the transformation of cities into hotspots of intentional and unintentional introductions of biodiversity because of land-use change to meet the needs of the growing human population such as open space recreation activities, gardening and landscaping (Kuhn et al., 2004). This makes urban areas ideal for introduction and thriving of non-native or invasive species as reflected by the spatial pattern of the successful introduction of invasive species (Fig. 5.4).

Threatened Species

Threatened species show a general low diversity in Greater Gauteng with the only exception being parts of the south-east grid cell, an area along the border of Gauteng and Mpumalanga provinces which showed spatial patterns of high proportional species diversity for Threatened species (Fig. 5.5).

The dominant habitat biome in the south-east grid cell is the grassland, specifically the Soweto highveld grassland within the Mesic highveld grassland of Devon. Devon

Grasslands IBA which is located within the south-east grid cell was only recently, in 2014 established as an Important bird area (IBA), with a size of about 75,330 ha (Marnewick et al., 2015). The area which showed the largest proportional diversity for Threatened species in Greater Gauteng overlaps with the location of the Devon Grasslands IBA (see Chapter Three). I show in Chapter three already the role Devon Grassland plays for avian conservation in Greater Gauteng.

The area around Suikerbosrand Nature Reserve however, did not show a large proportional diversity index for Threatened species. This observation could possibly be explained by the small size of the reserve (17000 ha) compared to Devon Grasslands (73000ha) alternatively, it could really be a weakness of the algorithm used which is worth further investigation. The IBA is also sandwiched between transformed habitats and landscapes bounded by agricultural lands and human settlements (Chapter Four). Devon Grasslands IBA on the other hand, though with an unprotected status, is relatively less disturbed by pressures of urbanization and habitat modification. The size of the habitat could also be crucial to the ecological functioning of the habitat as a refuge for threatened species with the Suikerbosrand IBA being significantly smaller in size than the Devon Grassland IBA.

The ability of the diversity index to highlight an IBA in Greater Gauteng indicates that this approach, when applied across less well-known landscapes with sufficient data coverage, has the potential to help discover other sites of conservation value for birds. A further application of this benefit could be for some ground truthing and assessment focused on areas highlighted as having large proportional species diversity. Ground truthing can involve a dedicated research team undertaking actual visits to the areas highlighted as contributing large absolute species or proportional diversity index. The aim of such visits will be intensive investigation where on the species, vegetation structure as well as environmental assessment. This will pay credence to the method employed in this chapter and a combination of this method and ground truthing can produce a very powerful conservation management and decision tool. This can also help highlight possible weakness of the method and strengthen its obvious positives as highlighted in the results of this chapter.

Waterbirds

Waterbirds have long been recognized as having special conservation needs (Kirby et al., 2008, Green and Elmberg, 2013). The Ramsar convention on wetlands of international importance is one of the measures in place to ensure adequate conservation measures and policies are aimed particularly at wetlands and their associated species. In South Africa, where 23 wetlands of international importance have been identified (Cowan, 1995), monitoring of waterbirds is usually carried out by complete counts of individual birds of all species at wetlands, such as the Coordinated Waterbird Counts (CWAC) (Taylor et al., 1999). A good understanding of the comprehensiveness of the network of wetlands in an area, is crucial to the success of waterbird survey programmes of that region (Dudgeon et al., 2006, Kirby et al., 2008). Fig. 5.6 can help with identifying the wetland network of Greater Gauteng and can improve coverage for the CWAC programme in Greater Gauteng. The first step is to list the pentad with a large value for the waterbird diversity index in Fig. 5.6. The second step is examine the topographical map and satellite photographs for these pentads, and to find the wetlands. These sites, or at least some of them, must have been pivotal in generating the large value for the waterbird diversity index. They can be checked against the list of wetlands already included in CWAC surveys. Candidate wetlands for inclusion in the set of those surveyed can be visited and their importance for waterbird conservation can be ground-truthed. Perhaps even more important is that pentads with small values for the waterbird diversity index can be positively identified as areas which lack wetlands. For example, Figure 1 of Taylor et al. (1999) shows the location of wetlands where waterbird surveys had taken place; but it completely fails in demonstrating whether the areas with no surveys have no wetlands, or whether the wetlands in them have not been surveyed. The algorithm of this chapter enables this distinction to be made.

Conclusion

There are two main benefits or applications that arise from this chapter. First is the use of the species diversity index in possible site selection for biodiversity conservation as demonstrated by the species diversity index highlighting areas with large proportional diversity of threatened species in Greater Gauteng. This confirms its sensitivity by highlighting the Devon Grasslands IBA (Chapter Three). Secondly, the species diversity index can also be applied for biodiversity monitoring as it showed for the non-native or invasive and urban species. A careful study of the spatial distribution plots generated by the indices can be an important policy and management tool aimed at efforts for monitoring the non-native invasive species as well as conserving native species. The ecological and biological applications arising species diversity index as shown in this chapter should ultimately lead to desired biodiversity monitoring and conservation goals at local and regional scales using atlas data generated by citizen science projects such as the SABAP2. There is also room for further development of the ideas from this chapter, such as investigating the patterns of distribution, richness and abundance of other animals and plant species in Greater Gauteng. Given that birds have been shown to be good biodincators, I will expect a similar pattern of richness and diversity to be observed in other biodiversity.

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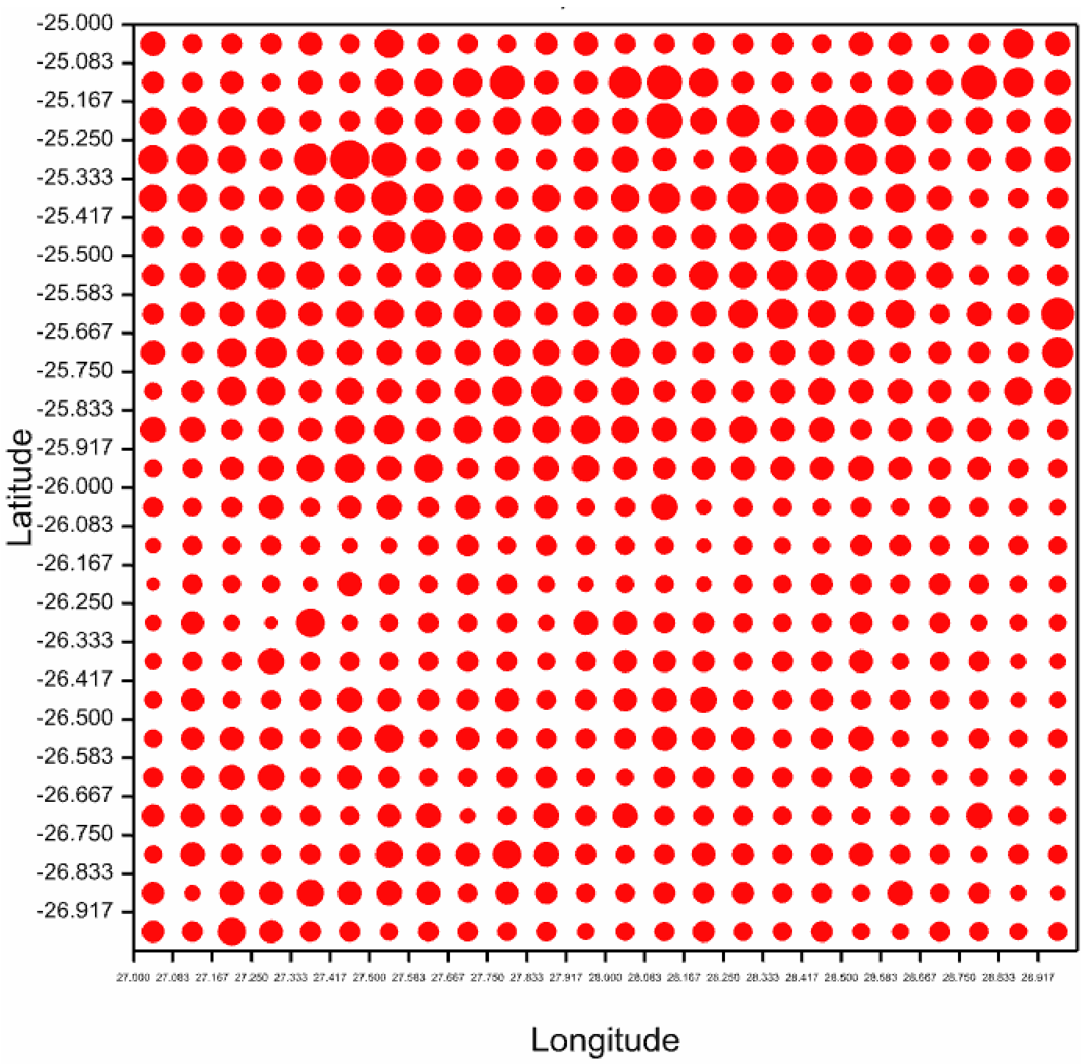

Fig. 5.2: Spatial distribution of absolute bird species diversity index for overall species per pentad in Greater Gauteng.

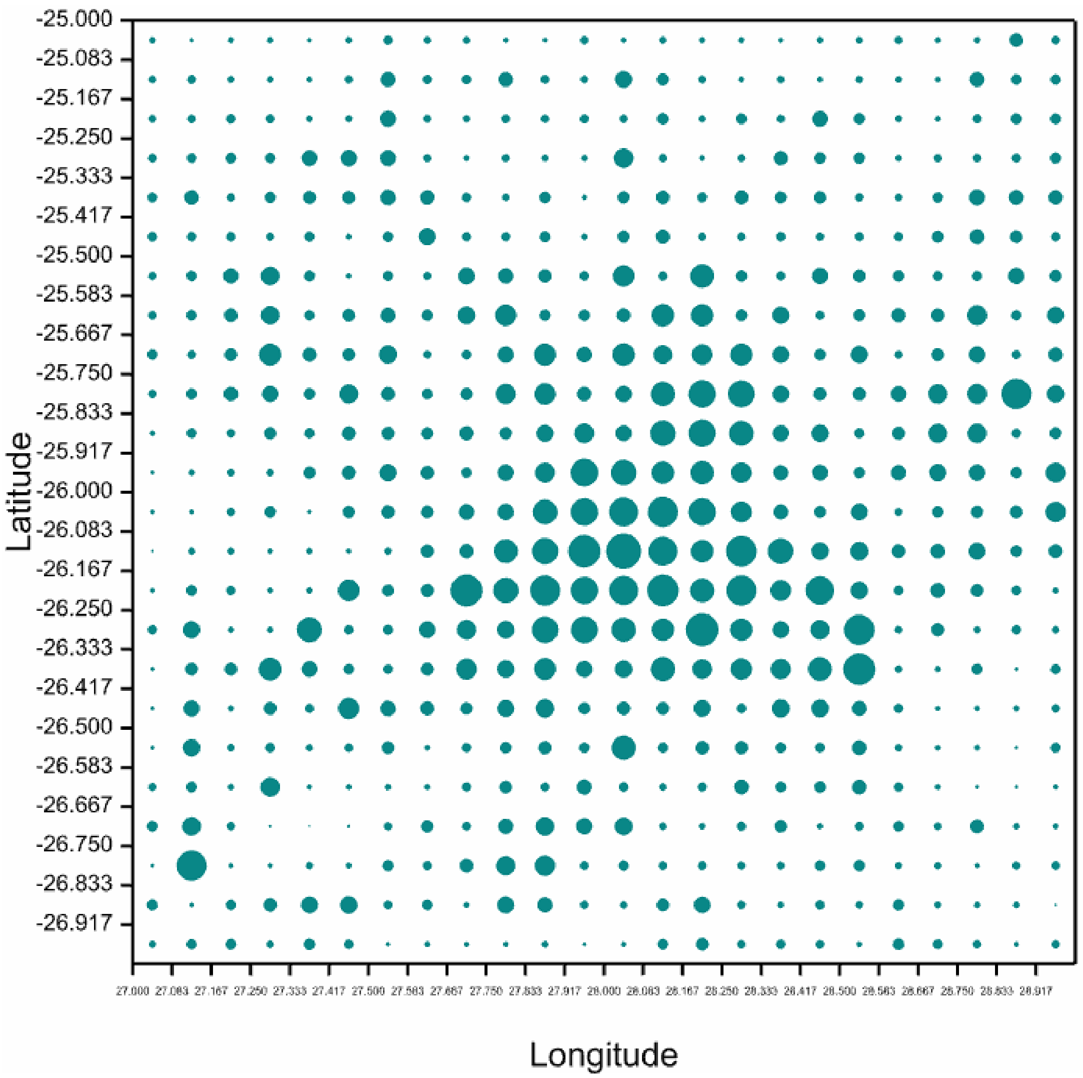

Fig. 5.3: Spatial distribution of species proportional diversity index for the sub-group urban species to the overall species diversity index per pentad in Greater Gauteng

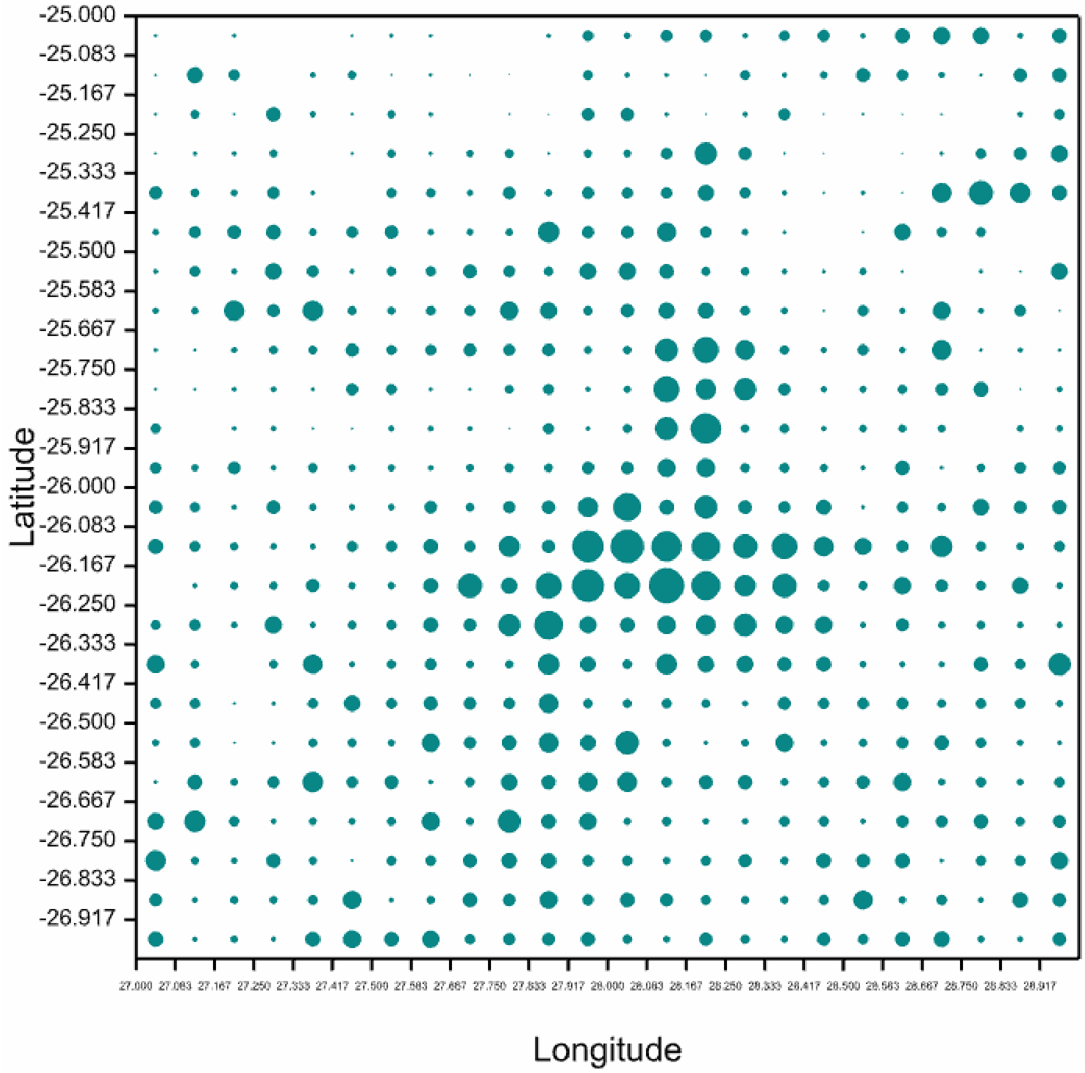

Fig. 5.4: Spatial distribution of species proportional diversity index for the sub-group non-native or invasive species to the overall species diversity index per pentad in Greater Gauteng.

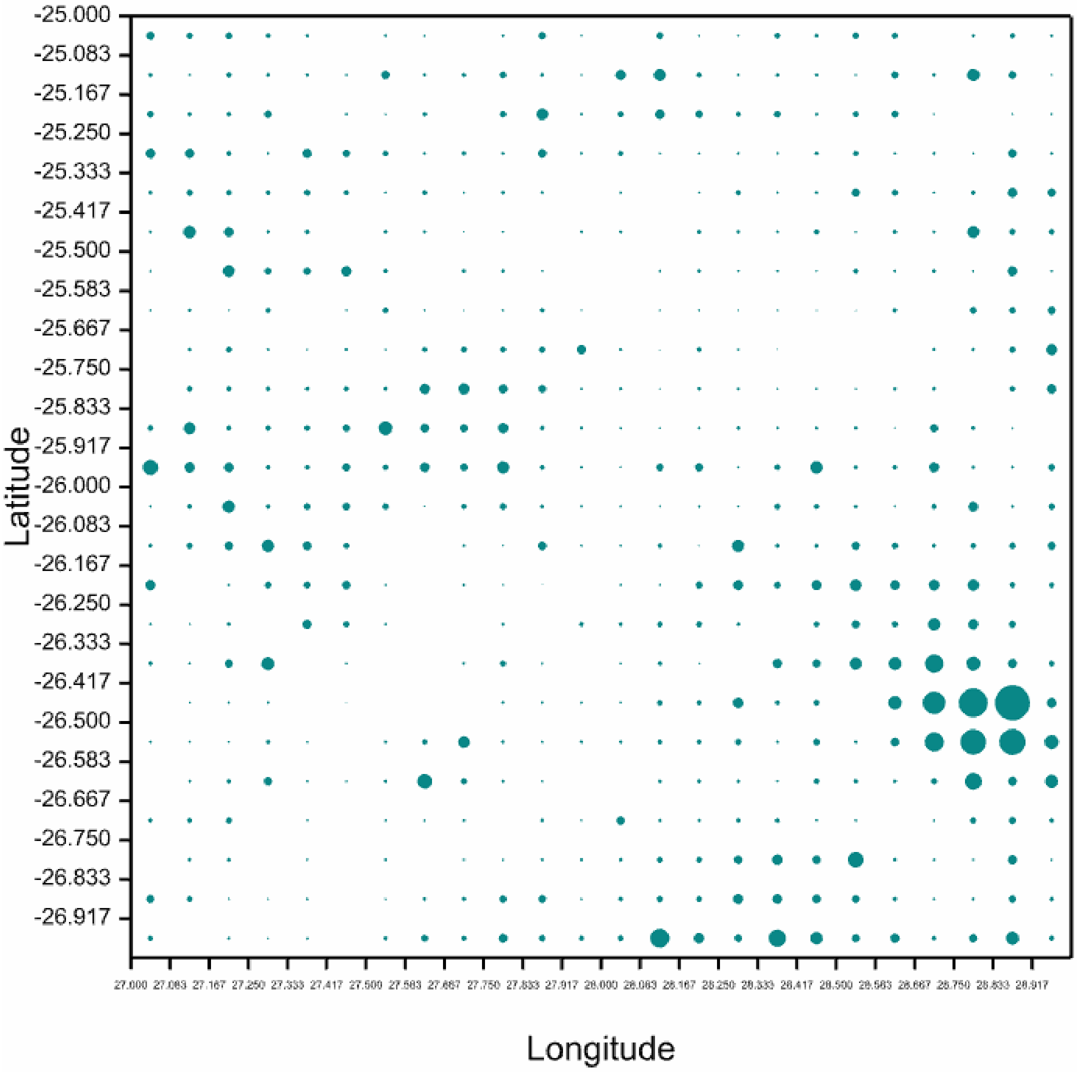

Fig. 5.5: Spatial distribution of species proportional diversity index for the sub-group Threatened species (IUCN Red-listed species facing regional threat to extinction) to the overall species diversity index per pentad in Greater Gauteng

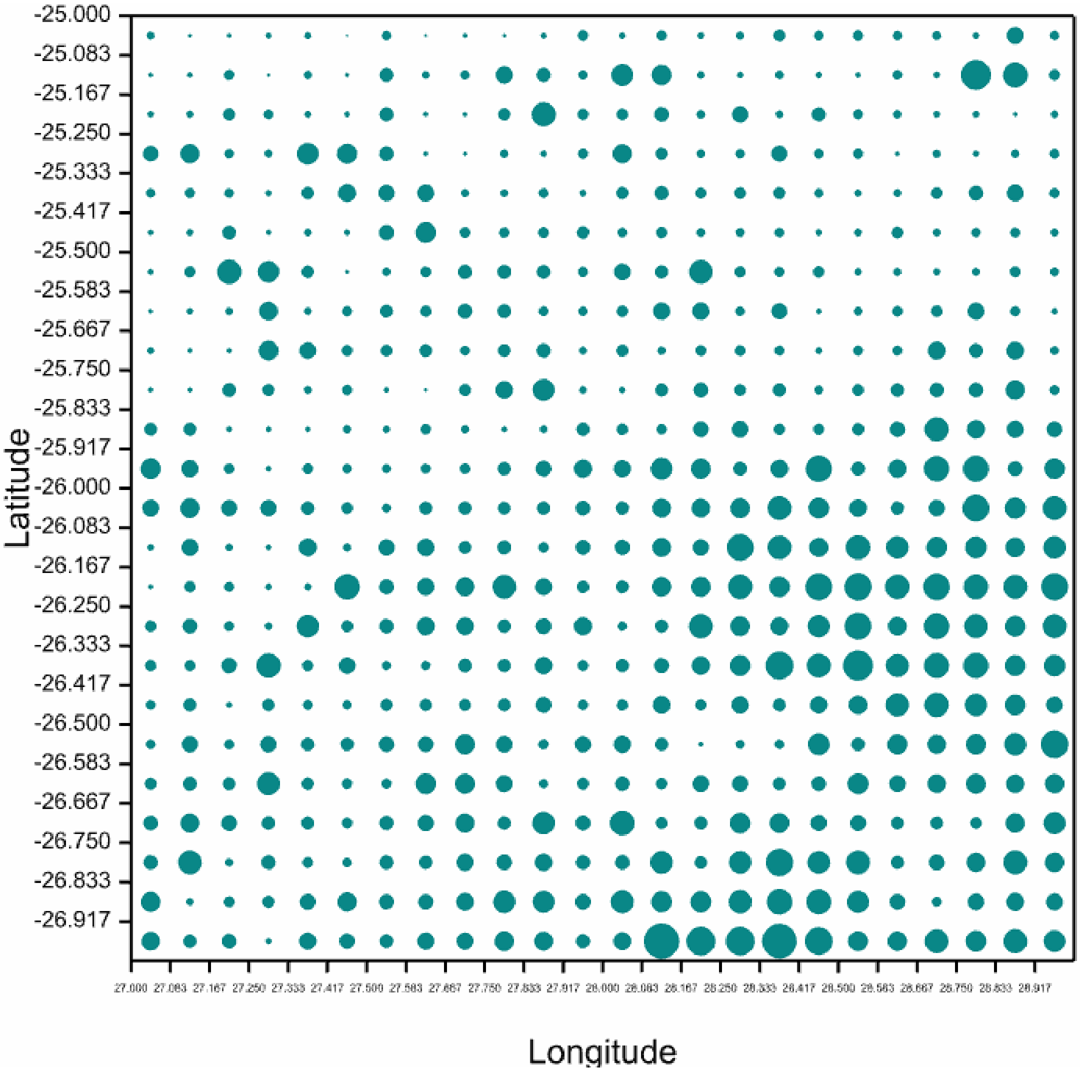

Fig. 5.6: Spatial distribution of species proportional diversity index for the sub-group waterbird species (bird species that utilize the inland water bodies) to the overall species diversity index per pentad in Greater Gauteng

Chapter Six

Relationships between bird communities and the human population in Greater Gauteng

Abstract

This chapter examines patterns between human population density and the reporting rates of birds in the 576 pentads of Greater Gauteng, where 30% of South Africa's human population occurs. The estimated number of people per pentad ranged from 20 to 533,650 (mean 25,273, median 1,814). Using SABAP2 bird atlas data, 263 bird species occurred in more than one quarter of the 576 pentads. For these species, the reporting rates for each of the 576 pentads were calculated and plotted against human population size per pentad. A smoothed line was fitted through the scatterplot for each species to aid the interpretation of the relationship between human population density and reporting rates. The 263 species were objectively classified into 18 groups, each with a similar pattern. In broad terms, 110 species showed increasing reporting rates with human population density, 75 species showed decreasing reporting rates, and 71 species had their largest (or smallest) reporting rates at intermediate values of human population density. This chapter provides rich insights into the variety of responses of birds in Greater Gauteng to human population density. The algorithm used in this chapter needs to be applied in other densely populated areas of South Africa and elsewhere in the tropical parts of Africa. The methods developed in this chapter provide descriptions of the multiple array of patterns in the relationship between birds and human populations; finding the mechanisms that underlie these patterns will be a challenging and valuable field for future study.

Introduction

The global increase in human population size has grown more than 10-fold from 600 million people in 1700 and is still increasing at a faster pace than at any previous time in history (Bloom and Canning, 2004, Peterson 2017). A consequence of the increase in human population size is the drift of human population traffic towards urban centres driven by socio-economic reasons in search of improved standard of life and better job opportunities (Cohen, 2003). Factors arising from the changes in spatial patterns of aggregation of human population are bound to influence the distribution and species composition of biodiversity, especially in and around urban areas. These factors are typically characterized by colonization and transformation of natural habitat by humans while competing with biodiversity for limited space and resources (Primm et al., 1995, Pimm and Raven, 2000). This is especially the case around the urban sprawl described as the expansion of human populations away from central urban areas into low-density, monofunctional surrounding areas (Gaston, 2010). Unplanned expansion of human settlement adds pressure to the natural habitat which is home to biodiversity (Gaston, 2010, Luck and Smallbone, 2010).

Comparatively few studies on the relationship between urban biodiversity and human population density have been carried out in Africa and other tropical regions in the southern hemisphere (Richardson et al., 1996, Rouget et al., 2003, Alston and Richard, 2006, Luck, 2007). This leaves a knowledge gap in urban biodiversity in this region. Studies of urban biodiversity have shown evidence across taxonomic groups at regional scales for a broad positive relationship between species richness and numbers of people living in an area (McKinney, 2002a, Araujo, 2003, Gaston and Evans, 2004). It has been suggested that this positive correlation between human density and species richness is linked to the spatial variation of environmental factors, such as net primary productivity (Francis and Currie, 2003). Furthermore, studies of biodiversity in European urban areas have also shown green spaces in urban areas such as small urban woodlands serve as biodiversity hotspots (Croci et al., 2008). Blair (2004), in a study carried in the USA, showed that urban sprawl affected local patterns of extinction and invasion of biodiversity at the community level, with species richness and diversity peaking at intermediate levels of urbanization. This phenomenon is linked to local extinction and invasion of species (McKinney and Lockwood, 1999, Chace and Walsh, 2006). With development of an area altering the vegetation structure of the landscape, the native species will undergo a local extinction and get replaced by invasive species which colonize the modified habitat (McKinney and Lockwood, 1999, Blair, 2004). The slight development of a site can create more heterogeneous conditions that support more invasive species of birds which explains the peak at intermediate levels of urbanization. The intermediate level of urbanization provides an array of heterogenous micro-habitat types which support an increase species diversity (McKinney and Lockwood, 1999). Severe development however, curtails the resources necessary for even the suburban-adaptable invaders (McKinney, 2002b, Chace and Walsh, 2006).

In this chapter, I examine patterns of spatial relationship patterns between human population density and the reporting rates and abundance of the more widespread bird species in Greater Gauteng. Human population density is a surrogate for level of urbanization (Luck and Smallbone, 2010). I explore the correlation between human population density and avian species richness in Greater Gauteng. As far as I know, the approach used in this chapter has not been carried out elsewhere. This algorithm provides a novel contribution to the field of urban biology and conservation. It also highlights the benefits of citizen scientists in driving and achieving regional and global biodiversity conservation goals. In terms of general data used by scientists for investigation. Citizen scientist also play a crucial role as observers of environmental change and can bridge the gap between scientific questions and answers (Luck and Smallbone, 2010, Ainsley, 2016, Underhill and Brooks, 2016).

Methods

Study area

Greater Gauteng (Fig. 1.1) is an area centered on the Gauteng province of South Africa. It is made up of four one-degree grid cells. For ease of description, the four grids are named per their coordinates and relative position to each other, they are; 25S 27E (“northwest”), 25S 28E (“northeast”), 26S 27E (“southwest”) and 26S 28E (“southeast”). The spatial extent of the four grid cells extends beyond Gauteng province, covering parts of the neighboring provinces of Limpopo, North West, Free State and Mpumalanga hence the reference of "Greater Gauteng". The area has 576 pentads, 270 of which make up the Gauteng province. Greater Gauteng is home to about 30% of South Africa's population with Gauteng alone accounting for 25% of the Country's total population. This makes the Greater Gauteng the region with the highest and most rapidly increasing human population in South Africa (Statistics South Africa, 2015, Ainsley, 2016, Underhill and Brooks, 2016).

Data and Analysis

Bird Distribution Data

Bird data was generated from summarized bird lists which were extracted from the database of the Second Southern African Bird Atlas Project (SABAP2). Checklists submitted to the project over the decade between June 2007 and January 2017 were included in the analysis for this chapter. Bird data were collected at the spatial unit of a pentad in accordance to the SABAP2 fieldwork protocol (Underhill, 2016). A pentad is a roughly rectangular unit measuring five minutes of latitude (9.2 km) by five minutes of longitude (c. 8.2 km) (Underhill and Brooks, 2016).

Greater Gauteng is the most intensively atlased region of South Africa; the 576 pentads that fall within the region have been regularly atlased since the project started in mid-2007, and each pentad had at least 11 checklists by June 2016 as a result of the SABAP2 “Four Degrees Blue” challenge. (Ainsley, 2016). This data-rich region makes it an ideal area to study and closely monitor changes in avian species diversity, distribution and abundance.

Human Population Data

The human population data were derived from the records of the 2011 South African Census (Statistics South Africa, 2015) obtained from the DataFirst Data Portal, University of Cape Town (https://www.datafirst.uct.ac.za/). I used these data to estimate the number of people in each pentad. The South African census data give the number of people living in various nested spatial units, with the smallest being the enumerator district. The spatial units that I used from the census were the irregularly shaped units called ‘sub-place’ and referred to by the variable name “SP_Code” in the dataset. In contrast, the SABAP2 data are at the pentad scale, and the challenge is to estimate the number of people in each pentad. I refer to the parts of each sub-place that fall within a pentad as blocks. Using Quantum GIS software (QGIS) (version 2.18.2), I obtained the area of each ‘sub-place’, and of each of its sub-components (which I refer to as blocks) that fall within one or more pentads, within the study region. I then calculated the proportion of each municipal area that falls within each block by dividing the area of the block by the area of the municipal area. I then used these proportions to derive an estimate of the number of people living in each block, by multiplying the total number of people in the municipal area by the block's proportion, and finally summing up the numbers of people in each block within the pentad. I assumed that people were uniformly distribution in each block. The data provided at this level are based on the actual census returns, and do not take under-reporting into account, which was estimated separately for each province; the under-reporting estimate for Gauteng was 15.2% and the average was 14.3% (Statistics South Africa, 2012). Thus, a further assumption is that there is no spatial variation in under-reporting.

Analysis

For each species that occurred in 144 (i.e. 25%) or more of the 576 pentads of Greater Gauteng, a scatter plot was produced. The x-axis was human population per pentad on a logarithmic scale, and the y-axis was the reporting rate, expressed as proportions between zero (absent from all checklists for the pentad) and one (recorded on every checklist). Each species plot has 576 points, one for every pentad. Because this is a census, and not a random sample of pentads from the population of 576 pentads, traditional statistical hypothesis testing is not appropriate. To describe the overall pattern of the relationship between reporting rates and human population, a smoothed line was fitted through the scatterplot for each species. I applied the same smoother to the scatter plot as developed by Summers et al. (1985, 1992) and Mullers et al. (2009); this used locally weighted averages to generate 20 smoothed values, calculated at equidistant points along a logarithmic scale, covering the range of human population values. These 20 points were used to plot (in red) a smoothed curve through the scatter plot for each species. The smooth curve through the 20 points was calculated using a spline function with degrees of freedom four.

The next step was to develop a dimensionless signature for each species, independent of the reporting rate, but which preserved the shape of the smoothed curve. In the time-honoured tradition of statistics, this was achieved by calculating the mean and standard deviation of the 20 points that define the smoothed curve, and standardizing them by subtracting the mean, and dividing by the standard deviation.

Because it is difficult to search visually for groups of species with similar patterns in their relationship with human population size, an algorithm to place species with similar signatures into groups was used. The chosen method was a non-hierarchical classification, developed by Friedman and Rubin, (1967). Non-hierarchical classification groups the species into a predetermined number of groups, on the basis of their signatures, so that each group contains species with similar signatures. Various criteria can be used to evaluate the performance of the algorithm; I maximized the total Euclidean distance between the groups, which is equivalent to minimizing the sums of squares-within groups. The analysis was performed using the Cluster directive of Genstat software 17th Edition (2014). The number of groups selected was based on the “elbow” method. The elbow method is a method of interpretation and validation of consistency within cluster analysis designed to help finding the appropriate number of clusters in a dataset (Malika et al., 2014). The basic idea is to define group of clusters such that the total intra-cluster variation (a measure of the compactness of the clustering) is minimized. The less the intra-cluster variation, the better. The elbow method looks at the total intra-cluster variation as a function of the number of clusters. The aim is to choose a number of clusters so that by adding another cluster doesn’t improve much better the total intra-cluster variation (Tibshirani et al., 2001, Malika et al., 2014).

Applying the elbow method to my data, as the number of groups increases the criterion (total Euclidean distance) initially decreases rapidly, but ultimately comes to a point where the gain in increasing the number of groups is relatively small (Malika et al., 2014). Choosing the position of the elbow, and therefore the number of groups, is subjective. The algorithm of Friedman and Rubin (1967) does not generate “nested” groups. At each group, the number of species within each group can vary substantially. This approach to the data constitutes an exploratory data analysis.

In reporting the results for each group, I select the scatterplot and smoothed curve for a representative species and discussing the observed pattern for the species. The choice of representative species for each group was guided by the extent of its distribution within the study area, estimated by the number of pentads in which the species was recorded. The graphs for the other species in each group are presented in Appendix 6.1. The smoothed curves for the species within a group are closely similar in shape (Appendix 6.1); there is thus no gain in presenting an “average” of the smoothed curves for the species in the group. This average is an abstract concept and selecting one species seems a more direct and informative approach to presenting the pattern for each group.

Results

Human Population

The number of people per pentad was estimated to range between 20, in pentad 2520_2725 (consisting mostly of the Vaalkop Dam Nature Reserve), and 533,650, in pentad 2600_2810 (Tembisa and the northern suburbs of Kempton Park). The spatial distribution of the human population in Greater Gauteng was not evenly distributed, appearing clumped around the city centres of Johannesburg and Pretoria Municipalities and other towns (Fig. 6.2). The mean number of people per pentad was 25,273. The median number of people per pentad was 1,814, which indicates the extent to which the distribution of people within the study area is skewed towards high human population. The lower quartile was 417 people, implying that 144 pentads have 417 or fewer inhabitants. The upper quartile was 12,488, so that 144 pentads have 12,488 or more inhabitants. The extent of the concentration of people in a relatively small number of pentads is highlighted by the fact that the mean is roughly double the upper quartile.

The estimated total population of the study area was 14,557,188 people. The total population of South Africa was estimated to be 51.8 million people during the 2011 census. This total figure includes the under-reporting adjustments (averaging 14.3%). Applying this adjustment to the estimated population of the study area suggests that 32% of the population of South Africa lives within Greater Gauteng. Most of Greater Gauteng however, is thinly populated. This is illustrated by the fact that only 13,578,104 people live in the 144 pentads with human population higher than the upper quartile (12,488), This means 93% of the human population lives within 25% of the area of Greater Gauteng.

Patterns of avian population distribution

A total of 263 bird species occurred in at least a quarter of the 576 pentads that make up Greater Gauteng (Appendix 6.1). The 263 plots for bird species population were then grouped by the elbow criterion algorithm into those with similar patterns. The "elbow" criterion suggested placing the species into 18 groups, placing species with similar population patterns into the same group. The numbering of the groups, as generated by the algorithm, is arbitrary. Figs 6.3 to 6.18 are scatterplots, showing the relationship between species reporting rate and human population size in Greater Gauteng for a representative species for each of the 18 groups. Plates 6.1 to 6.3 show the SABAP2 distributions within Greater Gauteng for each of these representative species. The species in each group are listed in Tables 6.1 to 6.18.

Groups 1 to 5 (Figs. 6.3 to 6.7, and Tables 6.1 to 6.5) consist of species showing a variety of patterns of negative correlation with human population as displayed by an overall decrease in abundance (deduced from the species reporting rates) as the human population increases. The species in Groups 6 to 8 (Figs 6.8 to 6.10, and Tables 6.6 to 6.8) display a variety of patterns of positive correlation with human population as displayed by the trend of increase in abundance of the bird species as the human population increases. Groups 9 to 18 (Figs. 6.11 to 6.20 and Tables 6.10 to 6.18) show a variety of alternative patterns, include groups of species which show maximum reporting rates at intermediate human population sizes, for example Group 11 (Fig. 6.13). The largest group was Group 5 which contained 26 species (Table 6.5), and the smallest was Group 18 with seven species (Table 6.18)

Group 1: This group is made up of 16 species (Table 6.1). The representative species for this group is the Red-billed Quelea *Quelea quelea*, with an occurrence range coverage of 572 of the 576 pentads of Greater Gauteng (Fig. 6.3, Plate 6.1). The species that make up this group reveal a pattern of steep decrease in reporting rates as human population increases; over the observed range of human population size, the smoothed line indicates that reporting rates decreased approximately six-fold with the increase in human population (Fig. 6.3). The highest reporting rates for the Red-billed Quelea were recorded in areas with low human population density and decreased rapidly with increases in human population (Fig. 6.3). The geographic distribution map of the Red-billed Quelea in Greater Gauteng also showed a pattern of high reporting rates in the south-west and south-east peripheries of the study area while showing low reporting rates in central areas of Johannesburg and Pretoria municipality which has high human density (Plate 6.1).

Group 2: This group is made up of 13 species (Table 6.2). The representative species for this group is the Swainson's Spurfowl *Pternistis swainsonii* with an occurrence range of 572 pentads (Fig. 6.4, Plate 6.1). The species that make up this group show, as in Group 1, a pattern of strong decrease, about three-fold, with increasing human population in Greater Gauteng (Fig. 6.4). The geographic distribution map of the Swainson's Spurfowl in Greater Gauteng shows a pattern that reflects this correlation, with the highest reporting rates for members of this group occurring in areas of low human population. The bird species in this group also appear to favour the grassland habitats showing low distribution in the savanna woodland habitats of Greater Gauteng (Plate 6.1).

Group 3: This group is made up of 12 species (Table 6.3). The representative species of this group is Yellow-crowned Bishop *Euplectes afer*, recorded in 514 of the 576 pentads (Fig. 6.5, Plate 6.1). The pattern for this group is broadly similar to that of Groups 1 and 2; however, the reporting rates of the species in this group show moderate decreases with increasing human populations, with the point of inflection at about 5,000 people (Fig. 6.5). In Group 3, the initial pattern of decrease appeared to be more rapid with the initial increase in human population than in Groups 1 and 2. The species in this group occur in areas with low human density and though reporting rates continued to decrease with increases in human population, the rate of decrease appearing to be eventually less sensitive to further increase in human population density. The geographic distribution map for the Yellow-crowned Bishop in Greater Gauteng indicates that the species appears to avoid areas of high human population (Plate 6.1).

Group 4: There are eight species in this group (Table 6.4). The South African Cliff-Swallow *Petrochelidon spilodera* whose range covers 388 of 576 pentads is the most widespread species in the group (Fig. 6.6, Plate 6.1). The South African Cliff-Swallow showed a similar pattern of early decrease in reporting rates which eventually became less sensitive to further increase in human population and flattened out at a lower level with increases in human population (Fig. 6.6). The point of inflection is at about 5,000 people. The geographic distribution map of the South African Cliff-Swallow reveals a preference for areas within the grassland biome of Greater Gauteng, showing low species distribution in the savanna woodland and high human populated areas of the Greater Gauteng (Plate 6.1).

Group 5: This group is made up of 26 species (Table 6.5). The Black-chested Prinia *Prinia flavicans*, recorded in 574 pentads, is the representative species for this group (Fig. 6.7, Plate 6.1). The reporting rate trend for the Black-chested Prinia showed it was marginally negatively correlated with human population status, but with an inconsistent overall pattern. The rate of decrease starts gently with initial increases in human population and appears to stabilize with a small increase in areas with medium human population density before decreasing slightly with further increases in human population (Fig. 6.7). Species in this group appear to prefer areas with low human populations but continue to thrive in areas with medium and high human density, with slightly reduced reporting rates. The geographic distribution map for the Black-chested Prinia in Greater Gauteng reflects this pattern (Plate 6.1).

Group 6: This group is made up of eight bird species (Table 6.6). The Rock Dove *Columba livia* is the representative species of this group, occurring in 507 pentads (Fig. 6.8, Plate 6.1). The relationship between the reporting rate of the Rock Dove and human population status shows an initial gentle increase giving way to a sharp increase starting around mid-population density which continues with further increase in human population density; the shape of the relationship is concave (Fig. 6.8). The geographic distribution map of the Rock Dove in Greater Gauteng shows a pattern that reflects the correlation with the highest reporting rates for the species in the urban centres of Johannesburg and Pretoria and low reporting rates found in the low human population density areas of Greater Gauteng (Plate 6.1).

Group 7: This group is made up of 16 bird species (Table 6.7). The Common Myna *Acridotheres tristis* is the most widespread species of this group, occurring in 574 pentads (Fig. 6.9, Plate 6.2). The pattern of change in reporting rates of the Common Myna shows a sharp increase with increases in human population densities. The shape of the relationship is convex, with the largest increase in reporting rates occurring at low human population densities (Fig. 6.9). This pattern shows species in this group have a strong positive relationship with human populations (Fig. 6.9). The geographic distribution map of the Common Myna in Greater Gauteng reflects this correlation too, with high reporting rates in the central areas of highest human population densities such as Johannesburg and Pretoria municipalities and surrounding areas, while avoiding areas with low human densities (Plate 6.2).

Group 8: This group is made up of 22 species (Table 6.8). The Southern Masked-weaver *Ploceus velatus* is one of three species occurring in all the 576 pentads that make up Greater Gauteng; the others are Laughing Dove *Streptopelia semitorquata* and Barn Swallow *Hirundo rustica* (Fig 6.10, Plate 6.2). The Southern Masked-weaver has a consistently high reporting rate across all areas of Greater Gauteng. The pattern of change in reporting rate shows a small increase with increasing human population density (Fig. 6.10). Most of the species in this group appear to be tolerant of anthropogenic disturbance and thrive well in all areas of Greater Gauteng; 15 of the 22 species in Group 8 occur in more than 75% (432 pentads) of the study area (Table 6.8). The geographic distribution map of the Southern Masked-weaver in Greater Gauteng shows a pattern that reflects this pattern of relationship with high reporting rates throughout Greater Gauteng (Plate 6.2).

Group 9: This group is made up of 16 species (Table 6.9). The Red-eyed Dove *Streptopelia semitorquata* is the most widespread species of this group, occurring in all the 576 pentads that make up Greater Gauteng (Fig.6.11, Plate 6.2). The pattern of change in reporting rates of the Red-eyed Dove is fairly stable up to a human population density of about 10,000 people and then shows a general increase with increasing human population density (Fig. 6.11). The pattern of increase in reporting rates can be described as late spike in reporting rates with increases in human population. The geographic distribution map of the Red-eyed Dove in Greater Gauteng shows a pattern that reflects this correlation with the highest reporting rates found in the urban centres of Johannesburg and Pretoria municipalities and low reporting rates in the low human population density areas of Greater Gauteng (Plate 6.2).

Group 10: This group is made up of 23 species (Table 6.10). The House Sparrow is the most widely distributed species of this group in Greater Gauteng, occurring in 540 pentads (Fig. 6.12, Plate 6.2). The pattern of relationship between the reporting rate of the House Sparrow and human population density shows variable increase in species reporting rate with increase in human population in Greater Gauteng; the point of inflection at which the increase in reporting rate starts is at around 1000 people (Fig. 6.12). The distribution map for the House Sparrow indicates a comparatively uniform distribution of reporting rates across the Greater Gauteng, with concentration on the areas with the largest human populations (Plate 6.2).

Group 11: This group is made up of 14 species (Table 6.11). The Arrow-marked Babbler *Turdoides jardineii* is the most widespread species of this group, occurring in 318 pentads in Greater Gauteng (Fig. 6.13, Plate 6.2). Group 11 is the first of a series of groups for which the smoothed curve shows a humped distribution pattern, with reporting rates first increasing with increasing human populations, reaching a maximum and then decreasing at the highest human population densities. The species in Group 14 show this pattern most clearly. The reporting rates for the Arrow-marked Babbler increase to a clear maximum at mid human population densities of around 1000 people per pentad (Fig. 6.13). The geographic distribution map of the Arrow-marked Babbler in Greater Gauteng shows a pattern that reflects this correlation with high reporting rates observed in peripheral towns of Mpumalanga, North West and Limpopo provinces such as Magaliesburg, Rustenburg, KwaMhlanga and Fafung while low reporting rates were observed in areas with very high or low human population densities. The Arrow-marked Babbler also shows a marked preference for the savanna woodland habitats (Plate 6.2).

Group 12: This group is made up of 11 species (Table 6.12). The White-winged Widowbird *Euplectes albonotatus* is the most widespread species of this group, occurring in 537 pentads (Fig 6.14, Plate 6.2). The pattern of reporting rates for the White-winged Widowbird follows a gentle curve showing early increases in reporting rates with increases in human population which is followed by a sharp decrease in reporting rates with increases in human population beyond about 50,000 people per pentad (Fig.6.14). The geographic distribution map of the White-winged Widowbird in Greater Gauteng shows a pattern that reflects this the relationship, with a conspicuous area of low reporting rates across the central part of the study area, where human populations are highest (Plate 6.2).

Group 13: This group is made up of 20 species (Table 6.13). The Red-breasted Swallow *Cecropis semirufa* is the most widespread species of this group, range covering 321 pentads (Fig. 6.15, Plate 6.3). The relationship between reporting rates of the Red-breasted Swallow and human population shows a slow but steady increase in reporting rates up to a human population of about 10,000 people per pentad, followed by a sharp decrease in reporting rates with further increases in human population (Fig. 6.15). The pattern of change in reporting rates of the Red-breasted Swallow appeared to favour areas with a medium human population density. Reporting rate of the Red-breasted Swallow is lower in areas of very high human population than it was in areas with low human population. The geographic distribution map of the Red-breasted Swallow in Greater Gauteng shows a pattern that reflects this correlation, with the highest richness of the species occurring in towns at the periphery of Limpopo and North-West provinces. This particular species occurs in savanna habitats of the northern half of Greater Gauteng (Plate 6.3).

Group 14: This group is made up of 13 species (Table 6.14). The Chestnut-vented Tit-babbler *Sylvia subcaerulea* is the most widespread species of this group, occurring in 393 pentads (Fig. 6.16, Plate 6.3). The pattern of reporting rates of the Chestnut-vented Tit-babbler shows a small increase in reporting rates to a maximum at around 10,000 people per pentad, followed by a sharp decrease in reporting rate with further increase in human population density (Fig. 6.16). The reporting rate was low in both low and high population areas and was comparatively higher at lower human population densities than at high human population densities indicating that the species has a comparatively higher tolerance for low densities than it has for high human density. The geographic distribution map of the Chestnut-vented Tit-babbler in Greater Gauteng shows a pattern that reflects this correlation, with high reporting rates in peripheral towns of Limpopo, North West and Free State Provinces that fall within Greater Gauteng while very low to no distribution is seen for the very densely populated areas of Greater Gauteng (Plate 6.3).

Group 15: This group is made up of 14 species (Table 6.15). The Spotted Flycatcher *Muscicapa striata* is the most widespread species of this group, occurring in 452 pentads (Fig. 6.17, Plate 6.3). The relationship between reporting rates of the Spotted Flycatcher and human population density follows a curve that is relatively flat, with a maximum at around 5000 people per pentad. Reporting rates increase gradually to the maximum and then decrease gradually with further increases in human population (Fig. 6.17). The geographic distribution map of the Spotted Flycatcher in Greater

Gauteng shows a pattern that reflects this correlation. High reporting rates were observed in peripheral towns of Mpumalanga, North West and Limpopo provinces while low reporting rates were observed in areas with very high or low human population densities. These species show a preference for the savanna habitats of the northern half of Greater Gauteng (Plate 6.3).

Group 16: This group is made up of 11 species (Table 6.16). The European Bee-eater *Merops apiaster* is the most widespread species of this group, occurring in 444 pentads (Fig. 6.18, Plate 6.3). The relationship between reporting rates of the European Bee-eater and human population density reveals an almost constant pattern (Fig. 6.18). The reporting rates of the members of this group appears to be insensitive or unresponsive to human population. The pattern follows a fairly uniform curve (Fig. 6.18). The distribution map of the European Bee-eater in Greater Gauteng shows a pattern that reflects this relationship; although it occurs sparsely in the southeastern degree cell, its pattern of occurrence in pentads elsewhere appears independent of human population size (Plate 6.3).

Group 17: This group is made up of 13 species (Table 6.17). The Natal Spurfowl *Pternistis natalensis* is the most widespread species of this group, occurring in 263 pentads (Fig. 6.19, Plate 6.3). The pattern of change in reporting rates of the Natal Spurfowl shows almost uniform reporting rates for the species until the human population density is about 5000 people per pentad, followed by a steady decrease in reporting rate with further increases in human population (Fig. 6.19). The pattern for members of this group differs to the pattern observed in species of Group 13 in that there is little evidence of an initial increase in reporting rates with human population size (Fig. 6.19). The atlas distribution map of the Natal Spurfowl in Greater Gauteng shows a pattern that reflects this correlation (Plate 6.3). Natal Spurfowl occurs fairly uniformly across the savanna habitats (mainly of the two northern degree cells) but shows lowest reporting rates across the northern part of the Pretoria-Johannesburg municipalities which intersects with its range.

Group 18: This group is made up of seven species (Table 6.18). The Egyptian Goose *Alopochen aegyptiaca* is the most widespread species of this group, occurring in 555 pentads (Fig. 6.20, Plate 6.3). The relationship between reporting rates and human population density for the Egyptian Goose reveals a U-shaped pattern; with minimum reporting rates observed at intermediate levels of human population (Fig. 6.20). The seven species in this group are all waterbirds (Table 6.18). This counter-intuitive relationship almost certainly reflects the dispersion of wetlands and is unlikely to be real.

Discussion

The primary aim of this chapter is an investigation using SABAP2 and human census data to detect spatial patterns between estimated human population densities and avifaunal distribution in Greater Gauteng. The results obtained showed that the reporting rates of many bird species show different patterns of spatial distribution with change in human population density in Greater Gauteng. The results of this chapter show the remarkable complexity of the variation in the pattern between human population densities per pentad and the reporting rates of the 263 bird species in Greater Gauteng recorded in a quarter or more of the 576 pentads within the study area. The elbow method, discussed above, suggested that the number of groups of patterns was 18, although in reality the differences between some of the groups are subtle. Although no statistical testing was performed (because the data comprise a census of a census of all pentads in the study area, and not a random sample of pentads) it is clear that for many of the 263 species, a substantial proportion of the reporting rate is accounted for by human population size per pentad.

This exploratory data analysis (Tukey, 1977, 1980) suggests that there are many functional forms to be explored to explain the relationship between human population size and reporting rates. This is clearly the next step in an ongoing analysis, beyond the scope of this chapter. It is not the density of people itself which impacts the birds but it is the way in which people at various population densities impact the landscape they live in which has direct impact on the birds (Trombulak and Frissell, 2000, Fahrig and Rytwinski, 2009). The next step therefore, will be to find explanatory variables which potentially have a causative linkage to the observed dynamics in avifauna reporting rates. Examples of the explanatory variables could be measure of the extent of paved area in each pentad, or the extent of savanna habitats (and its fragmentation state), or the area of suburban gardens (Savard et al.,2000, Fahrig and Rytwinski, 2009).

In spite of the fact that only the single explanatory variable of human population size was used, there is only one group of seven species for which the results are clearly counter-intuitive, Group 18, which consisted of eight species, all waterbirds (Table 6.18). The observed U-shaped pattern (Fig. 6.20) is probably a consequence of an uneven distribution of suitable wetlands for these species (Gibbs, 2000, Li et al., 2010), with more-than-expected numbers of wetlands in the pentads with low and high human populations. Studies have shown that natural wetland habitats and biodiversity are negatively affected by close proximities to increased human population densities (Li et al., 2010). If this was to be the case in Gauteng, I would expect decreased reporting rates in the areas with more human population densities. Another possibility worth investigating is whether the wetlands in the low human density pentads are natural, and those in the high human density pentads are artificial, such as at sewage works, and the wetlands associated with the mining industry.

The analysis of the distribution of the human population showed that 93% of the population within the study area lived in the 144 pentads with estimated populations larger than the upper quartile (12,488 people). It is tempting to conclude that it is the people in these pentads who have the largest impact on bird distributions. An inspection of Figs 6.2 to 6.20 reveals that the range of human populations in which the trajectory in the rate of change of reporting rates shifts are mostly below this upper quartile. In other words, the impact on most species of relatively small human populations per pentad can be decisive.

Group patterns of avifaunal reporting rates with changes human population density in Greater Gauteng

I have condensed 17 of the 18 groups into three broad categories of patterns, based on overall patterns of relationship between reporting rates and human population density in Greater Gauteng. The groups and given names partly adopted from previous research: Gainers, Losers and Adapters (Kark et al., 2007, Croci et al., 2008). The patterns for each category are unique to the species in the group and highlight the peak of the reporting rates as well as the direction and where possible rate of change in reporting rates in relation to human population. Group 18, the U-shaped group (Fig. 6.20), is not considered here, because as discussed earlier, this pattern is probably related to an uneven distribution of wetlands in relation to human population, a situation which has also been reported in previous research (Gibbs, 2000).

The Gainers Category: This category is made up of the 110 species of Groups 6, 7, 8, 9, 10, 11 and 12 which benefit from increasing human populations to a greater or lesser extent. The species that make up this category show a positive pattern of increasing reporting rates with increasing human population in Greater Gauteng. Two broad hypotheses have been put forward to explain this pattern of positive reporting rates with increases in human population density: (i) Human activities creating a habitat mosaic which supports the high reporting rates, and (ii) Adequate conservation measures offered by humans which maintains the positive correlation with human population in the landscape of the suburban environment (Hugo and Van Rensburg, 2008). These two hypotheses explain to a large degree the observed pattern of reporting rates for species in this category. Previous research by Hugo and Van Rensburg (2008) carried in South Africa also observed positive correlations between reporting rates and human population density. However, the research was carried out on a broader scale (national) and a coarser spatial unit (quarter degree). Another possibility that could explain this observed pattern is that more people are likely to spot more birds where they live which means species in areas with more people are likely to have increased reporting rates.

Species which fall in this category include three invasive alien species, Rock Dove, Common Myna and House Sparrow, as well as common resident bird species such as the Pied Crow *Corvus albus*, Dark-Capped Bulbul *Pycnonotus tricolor*, Hadeda Ibis *Bostrychia hagedash*, Cape Sparrow *Passer melanurus*, Southern Red Bishop *Euplectes orix*, Speckled Mousebirds *Colius striatus* and African Sacred Ibis *Threskiornis aethiopicus*. Most species in the dove (*Columbidae*) family (Red-eyed Dove, Cape Turtle-Dove *Streptopelia capicola*, Laughing Dove and Speckled Pigeon *Columba guinea*) except for the Namaqua Dove *Oena capensis* also showed this pattern. Increased species richness and abundance with increasing human population has been previously reported (McKinney, 2002b, McKinney, 2006). Certain human activities such as planting gardens with native plant species and maintaining nature parks have been shown to benefit common species especially by increasing habitat heterogeneity and productivity because common species tend to be more flexible than rare species in response to human activity. Furthermore, while urbanization results in loss of native species, it is thought in turn to promote an increase in alien species (Kowarik, 1995, Marzluff, 2001, McKinney, 2002b, 2006). This pattern is partially reflected by the species in Greater Gauteng. Only three of the 85 gainers are alien invasives. As expected, none of these species is in "Threat" Categories (Taylor et al., 2015).

The Losers Category: This encompasses the five groups, containing 75 species, that decreased in reporting rate with increasing human population per pentad, Groups 1, 2, 3, 4 and 5. The losers all attain peak reporting rates at low human population areas. All of the 75 species in this category (Tables 6.1 to 6.5) are indigenous; none of them is a species which would be anticipated to be more common in suburban than in rural areas (Hockey et al., 2005, Parker, 2012). Only one species – Secretarybird - of the 75 species in the losers category is in the regional IUCN "Threat" category (Taylor et al., 2015); this is most likely due to the selection of species that occur in 25% of the pentads in the study area, and which are therefore relatively common.

Studies have shown that anthropogenic disturbances such as construction and expansion of towns and cities as is the case in Greater Gauteng, promotes loss of native species (Bertin, 2002, McKinney, 2006). The distribution maps of many of the species in this category provide a possible explanation of the observed patterns of decreasing reporting rates with increasing human populations. Many species of this group are grassland species such as Red-billed Quelea, Swainson's Spurfowl, Black-chested Prinia and Yellow-crowned Bishop. They have their distribution centred around the grassland habitats of Greater Gauteng. It is also known that grassland habitat is irreparably altered with the transformation of rural and suburban areas, even where green spaces such as gardens and parks occur in urban areas; the vegetation in these green parks or gardens is often characterised by trees and other forms of exotic flora, thereby creating a habitat unsuitable for the survival native bird species. Also, the grass lawns are trimmed and maintained for aesthetic value at the expense of the biodiversity. As human population continues to grow and expand in Greater Gauteng into the grassland habitats, the grassland species are the main losers because their habitat is increasingly lost through human activities such as residential development projects and road construction, habitat modification for aesthetic goals, habitat degradation and fragmentation (Bertin, 2002, McKinney, 2006). With increasing human population, the reporting rates of these biome-specific species will suffer perhaps irredeemably unless appropriate conservation measures are put in place such as implementing bird-friendly management practices by land owners and managers, monitoring of grassland bird species which can be driven by SABAP2 as well as strategic designation and maintaining permanent preservation areas in the region where the habitat is maintained as best as possible to its pristine form in terms of vegetation structure and composition (McKinney, 2006, Sadler et al., 2010).

The Adapters Category: These are species reach a maximum level of reporting rates in areas with intermediate human population density. A total of 71 species was in the five groups which showed this pattern. Previous studies have reported species becoming most abundant at moderate levels of urban development, with reduced species richness occurring at high and low levels of urbanization (Blair, 2004, Smith and Wachob, 2006, Chace and Walsh, 2006, Luck and Smallbone, 2010). Reporting rates along the gradient of low-high human population density have been shown to display a hump-shaped pattern. This is consistent with the intermediate disturbance hypothesis which predicts species richness to be highest in intermediate levels of disturbance (Connell, 1978, Fisher et al., 2012).

In Greater Gauteng, five of the 18 groups containing 71 species (Groups 13 (Fig. 6.15), 14 (Fig. 6.16), 15 (Fig. 6.17), 16 (Fig. 6.18) and 17 (Fig. 6.19)) displayed a pattern consistent with the intermediate disturbance hypothesis where the peak of reporting rates in these species was observed in areas with medium human population density. This observed pattern in reporting rates agrees with previous studies on birds (Sewell and Catterall, 1998, Blair, 2004, Chace and Walsh, 2006, Devictor et al., 2007, Ortega-Álvarez and MacGregor-Fors, 2009). Other species have also been shown to display similar pattern of richness along the urban disturbance gradient (Germaine and Wakeling, 2001, Swihart et al., 2006). The pattern displayed by the species in this group could possibly be explained by the increase in resources at moderate level of human population and anthropogenic disturbance. Features which could potentially attract birds are the gardens around farm houses, avenues of planted trees, a mosaic of fields created by small-scale agriculture, constructed wetlands such as farm dams, parks and other green spaces which are a common characteristic of these areas. At low to moderate human population densities, the landscape consists of a mosaic of natural and transformed vegetation, with extensive edge effects. These transformed landscapes provide rich resource for food and shelter for the species owing to the more heterogeneous landscape of these areas with moderate human population density (Melles et al., 2003, Fairbanks, 2004, Gaston et al., 2007, Young et al., 2007).

Furthermore, McKinney (2006) concluded that the species which show the hump-shaped pattern of reporting rates are those that occupy the suburban habitats. This group of species often made up of native species persists to become regionally widespread (McKinney, 2006). These species typically consist of ground-foraging, omnivorous and frugivorous bird species that can utilize gardens, forest fragments and many other habitats available in the suburbs. My findings do partially support this conclusion. Several of the species in the adapter category fall under feeding guilds identified by McKinney (2006) as urban adapters. However, unlike the study of McKinney (2006), several of the species in the adapter category are not native species. This observed variation from previous research could possibly be explained by the difference in spatial resolution and grain size of the bird distribution data (Dungan et al., 2002). My research had a regional focus and a spatial unit of a pentad. This is in comparison to previous research that often focuses on broader spatial scope than the regional limit used in my research and at coarser spatial scale than the pentad. The quality of data for my research is also high with each of the 567 pentads that cover Greater Gauteng extensively atlased consistently over the last 10 years that this research has focused on.

Conclusion

The outcome of this chapter is of conservation significance to the avifauna in Greater Gauteng. The information contained in the various patterns of spatial distribution of many bird species with change in human population density can be applied with to understand the current state of bird species in Greater Gauteng. Also, with increasing human population due to urbanization in the region, we can have an idea how this dynamic will affect the distribution of bird species. Specific conservation programmes targeted at avifauna can therefore be tailored for specific areas and suburbs based on the spatial distribution pattern of the species.

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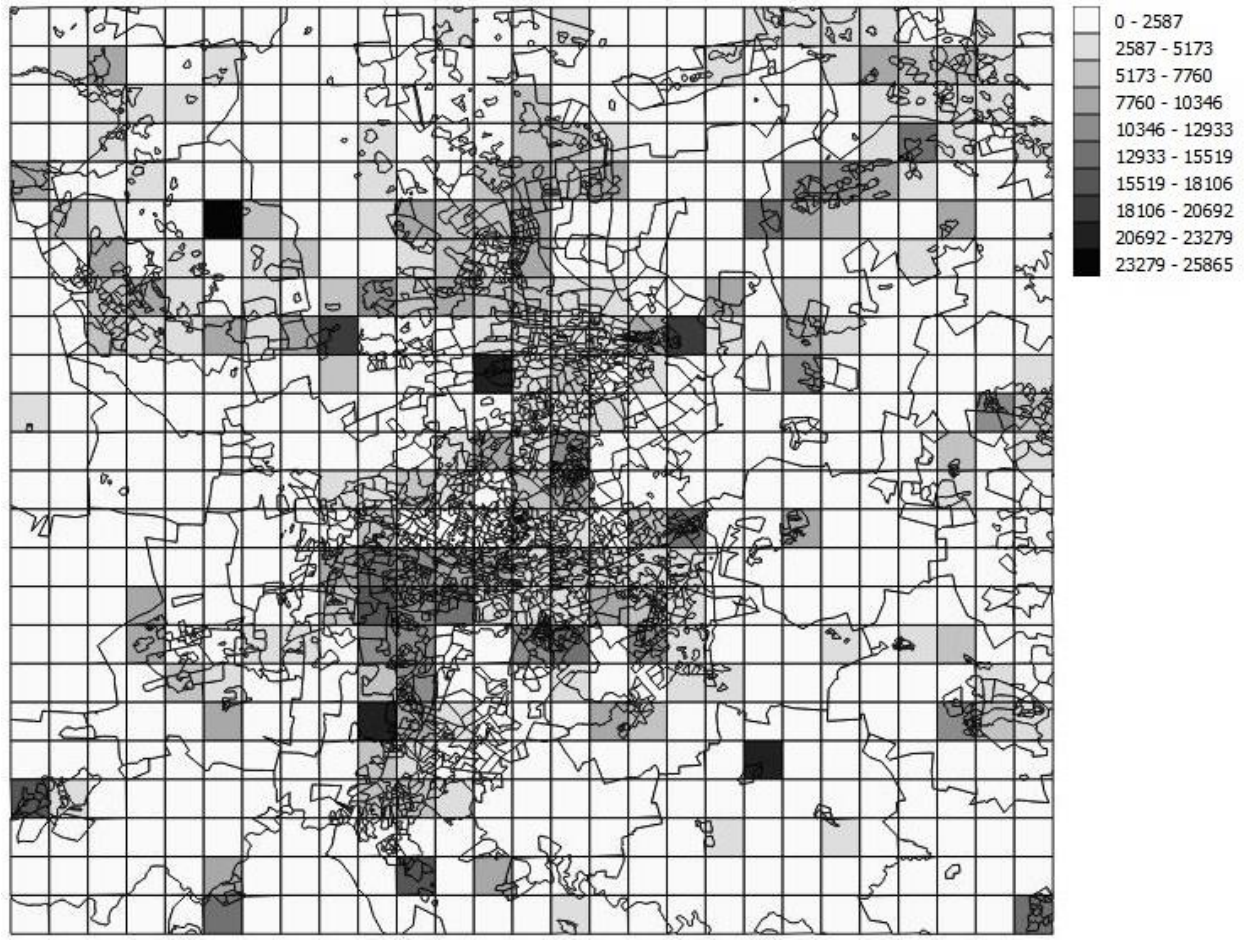

Fig. 6.2: Spatial distribution of human population densities in Greater Gauteng

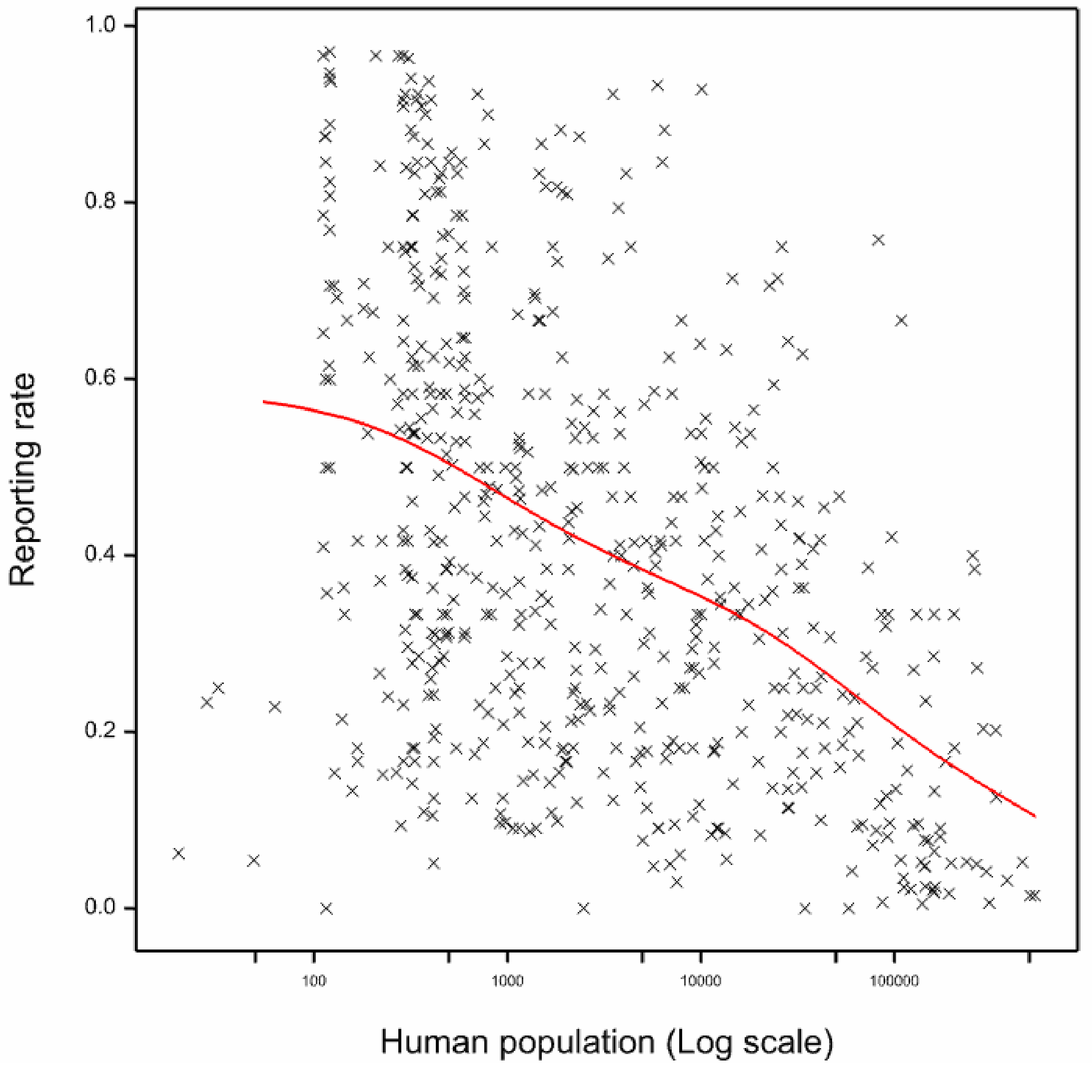

Fig. 6.3: The relationship between reporting rate of the Red-billed Quelea (representing bird species in Group one) and log of the human population in Greater Gauteng.

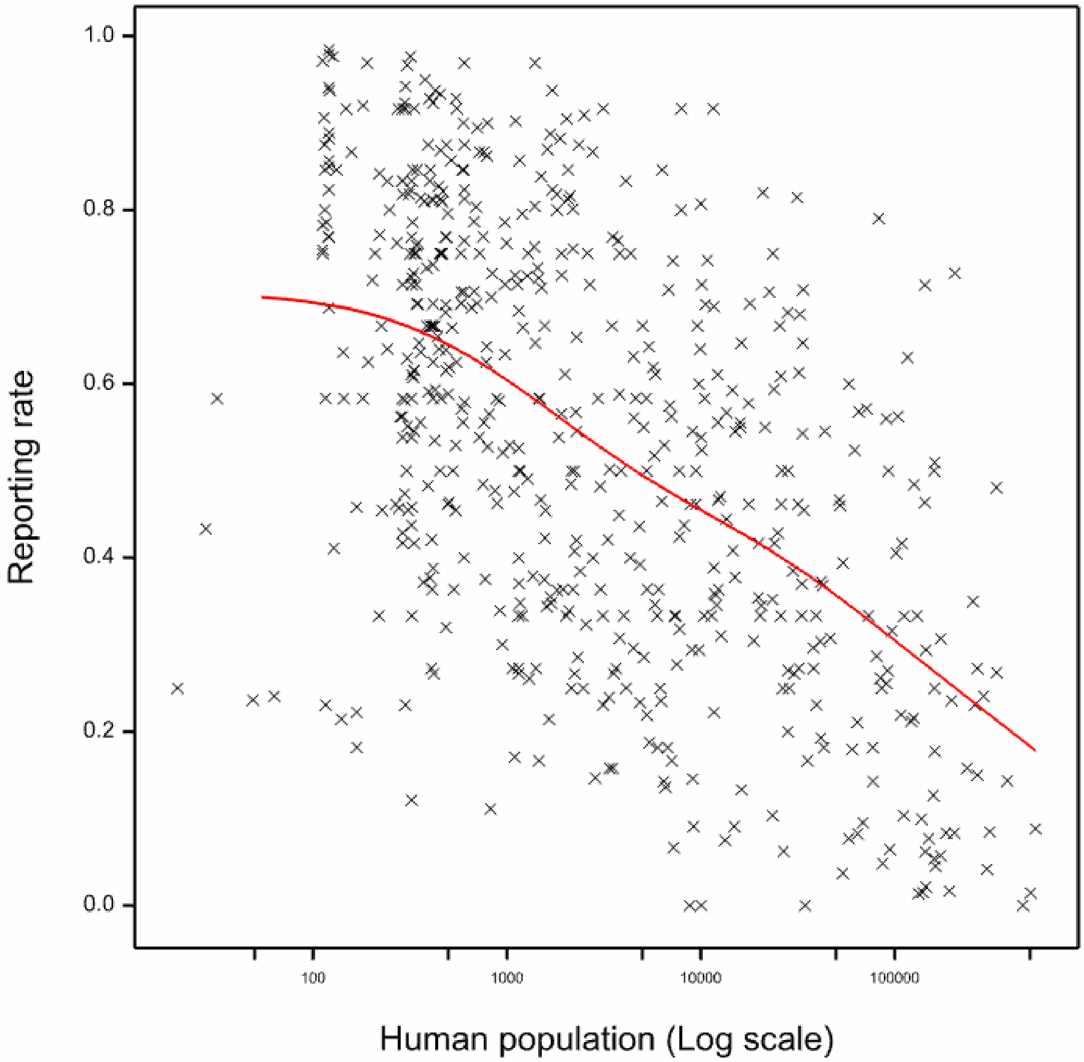

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Fig. 6.4: The relationship between reporting rate of the Swainsons Spurfowl (representing bird species in Group two) and log of the human population in Greater Gauteng.

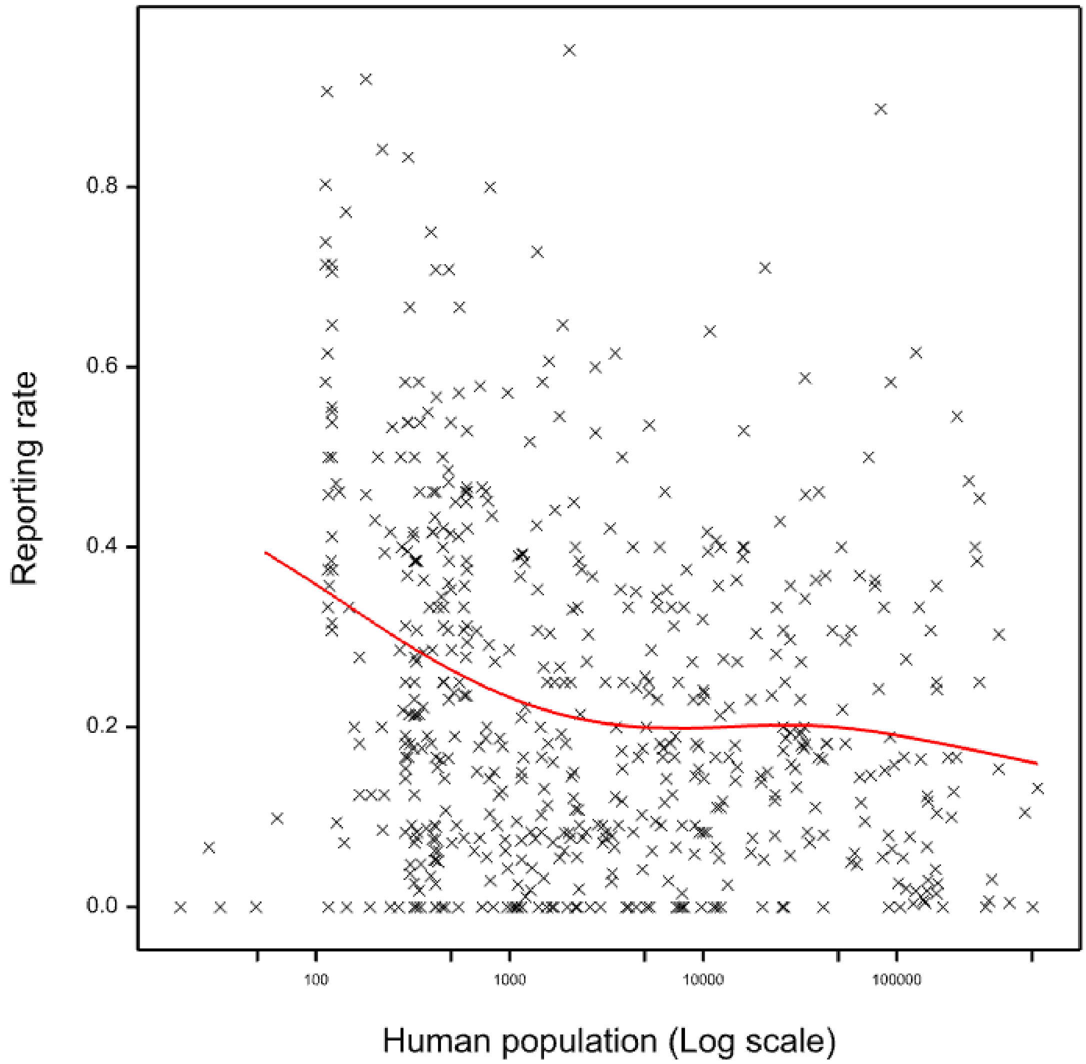

Fig. 6.5: The relationship between reporting rate of the Yellow-crowned Bishop (representing bird species in Group three) and log of the human population in Greater Gauteng.

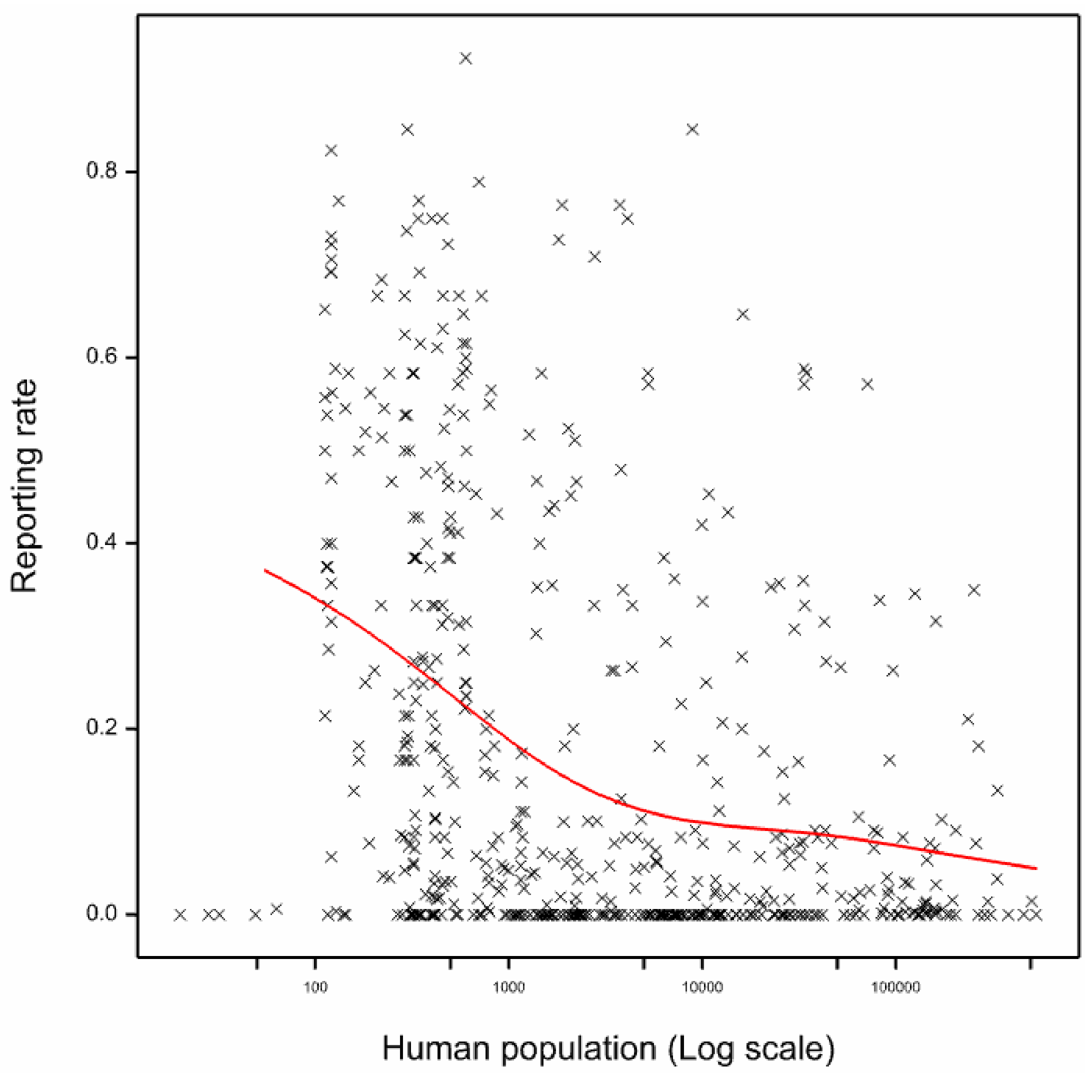

Fig. 6.6: The relationship between reporting rate of the South African Cliff-Swallow (representing bird species in Group four) and log of the human population in Greater Gauteng.

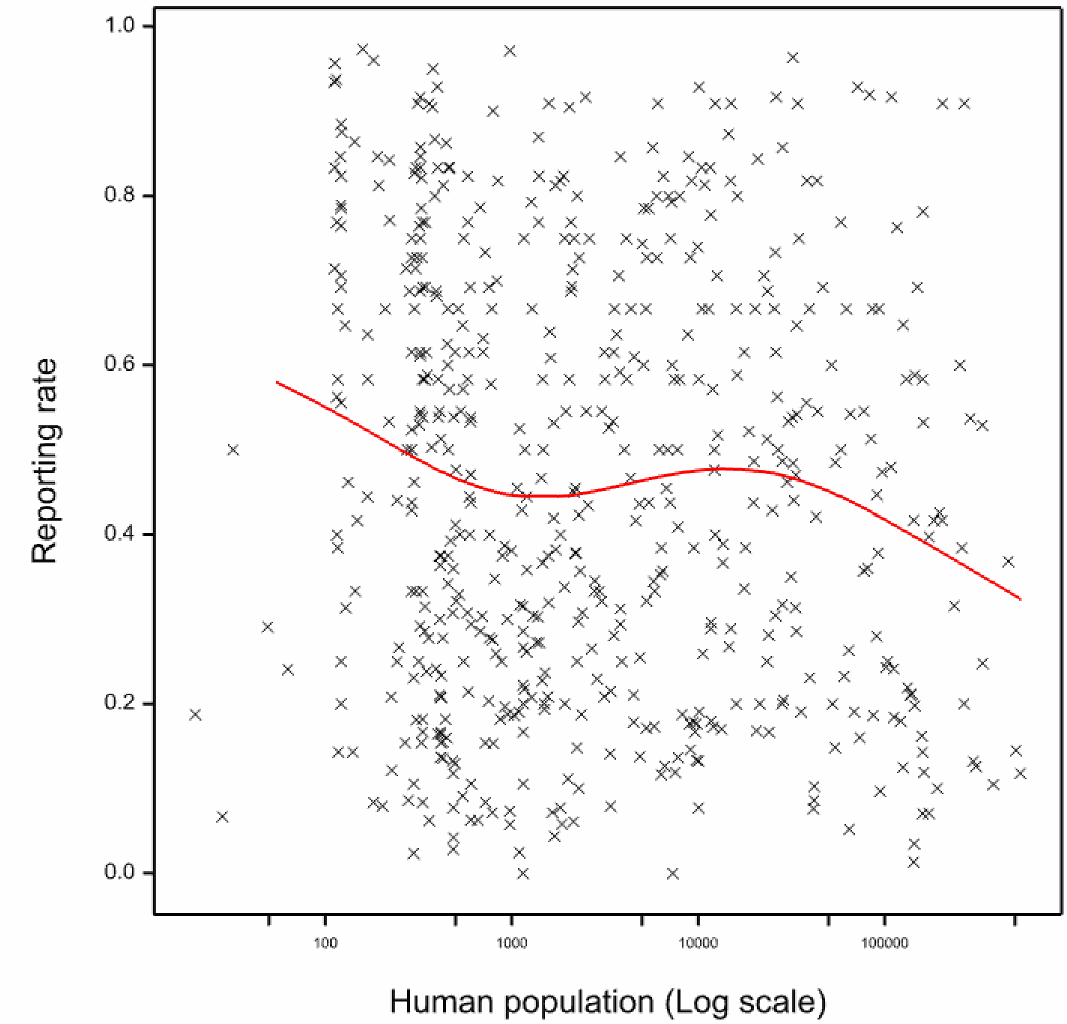

Fig. 6.7: The relationship between reporting rate of the Black-chested Prinia (representing bird species in Group five) and log of the human population in Greater Gauteng.

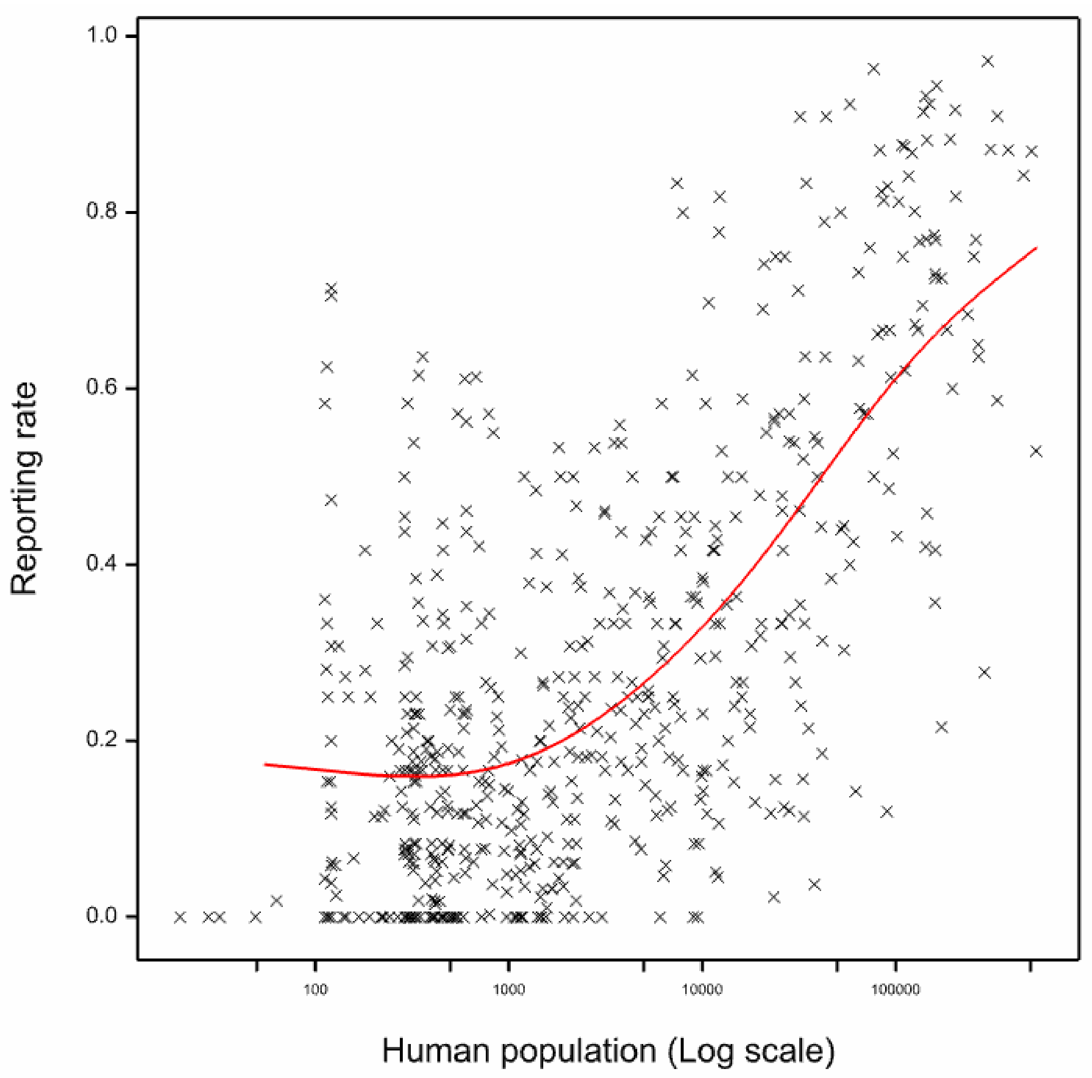

Fig. 6.8: The relationship between reporting rate of the Rock Dove (representing bird species in Group six) and log of the human population in Greater Gauteng.

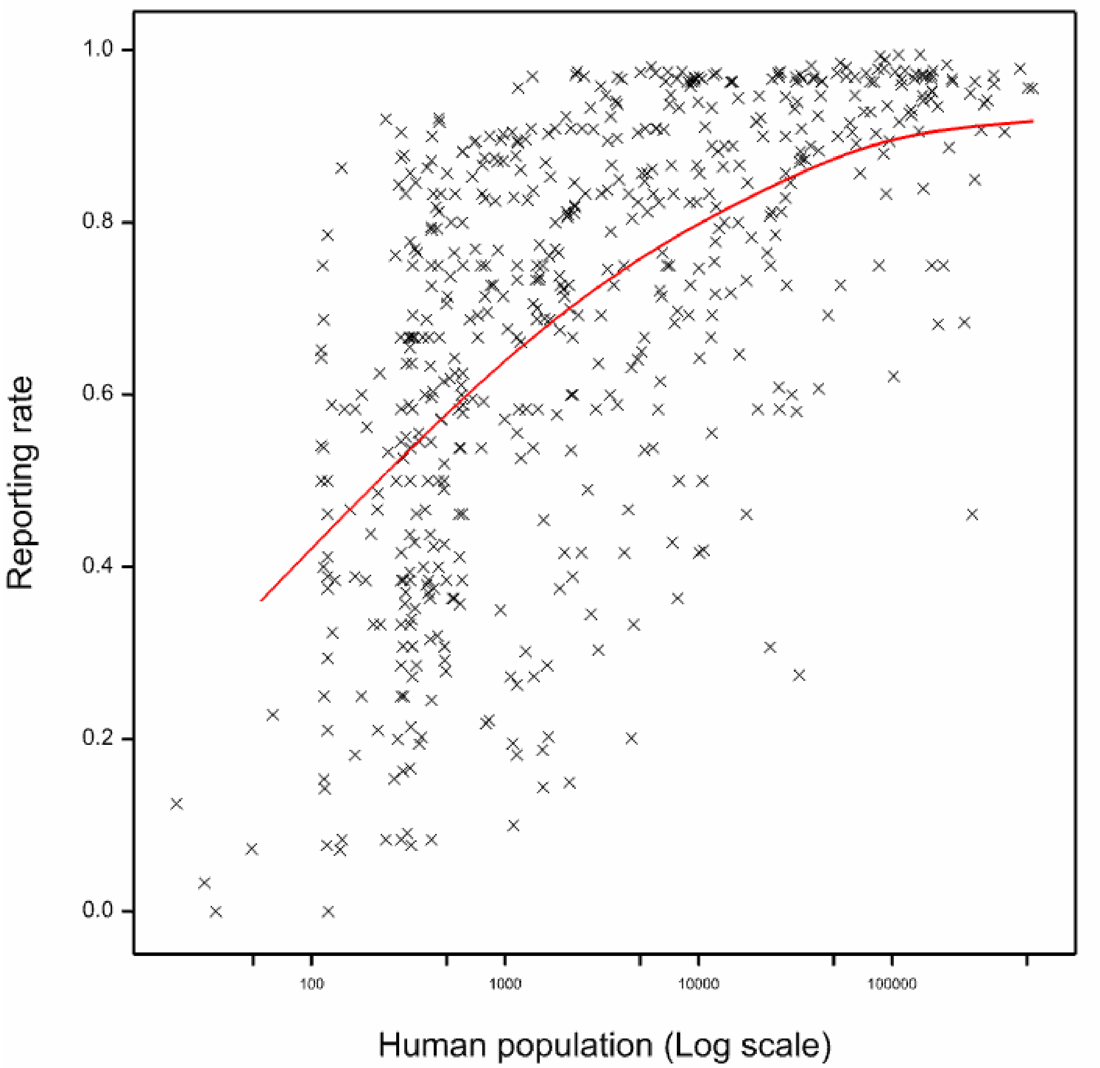

Fig. 6.9: The relationship between reporting rate of the Common Myna (representing bird species in Group seven) and log of the human population in Greater Gauteng.

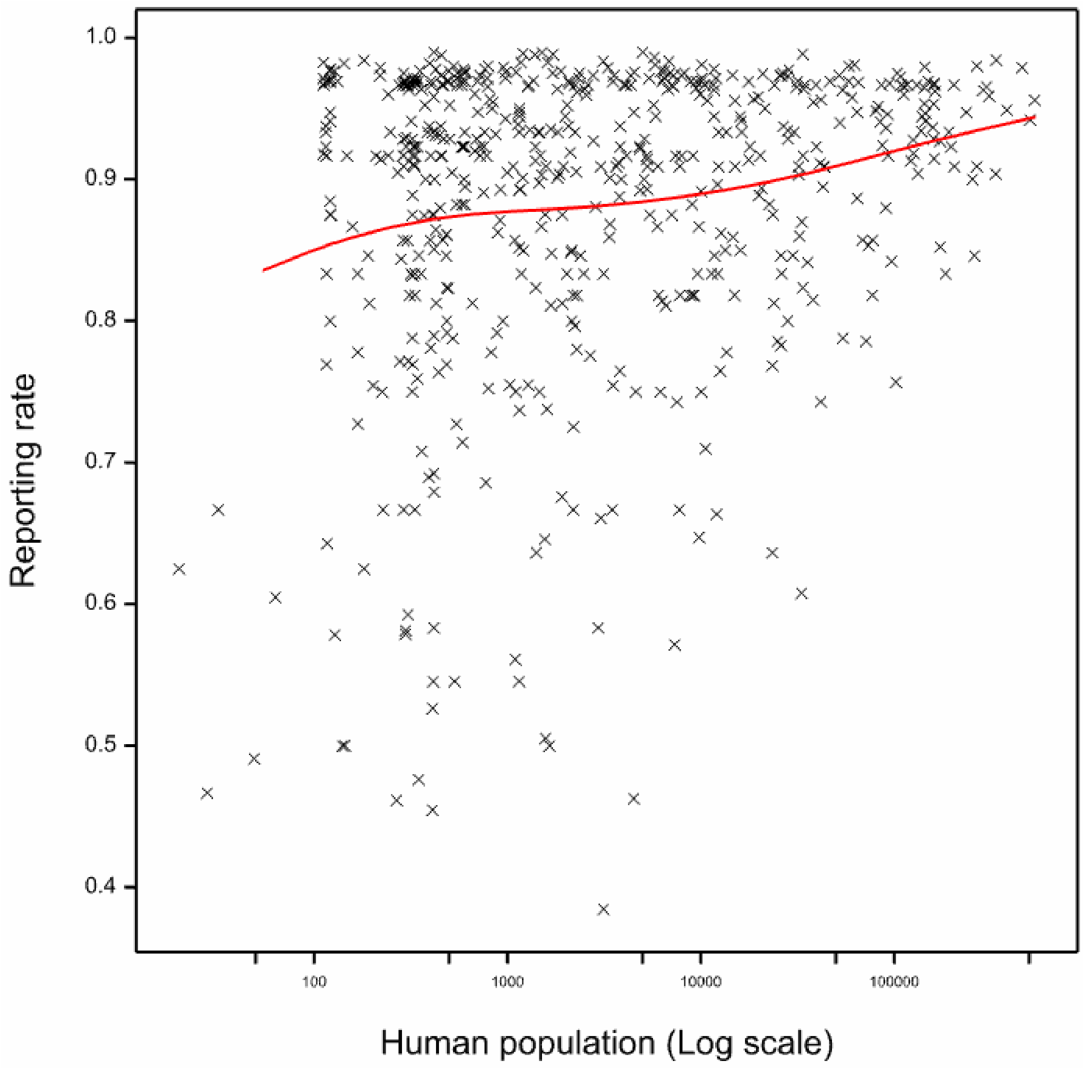

Fig. 6.10: The relationship between reporting rate of the Southern Masked-weaver (representing bird species in Group eight) and log of the human population in Greater Gauteng

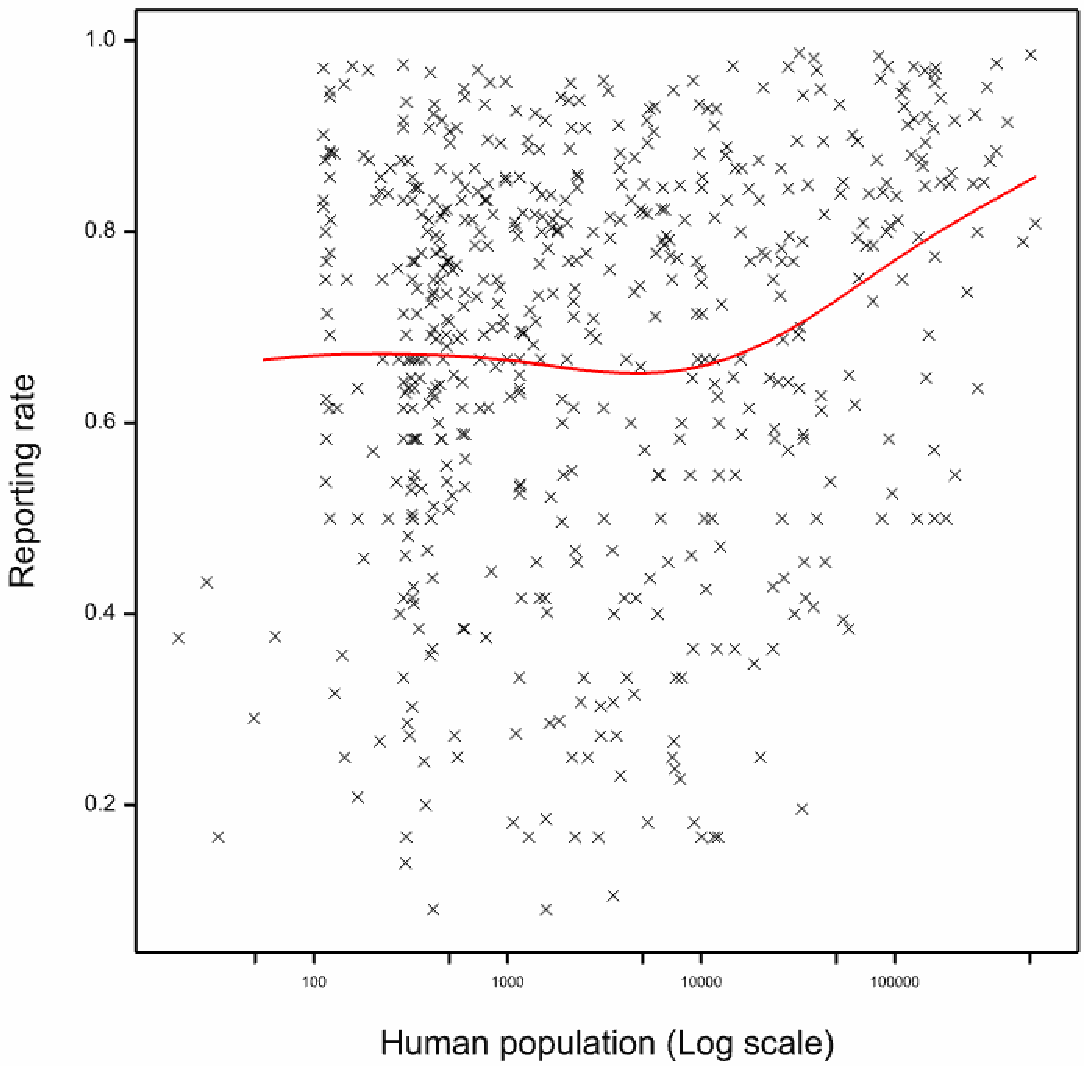

Fig. 6.11: The relationship between reporting rate of the Red-eyed Dove (representing bird species in Group Nine) and log of the human population in Greater Gauteng.

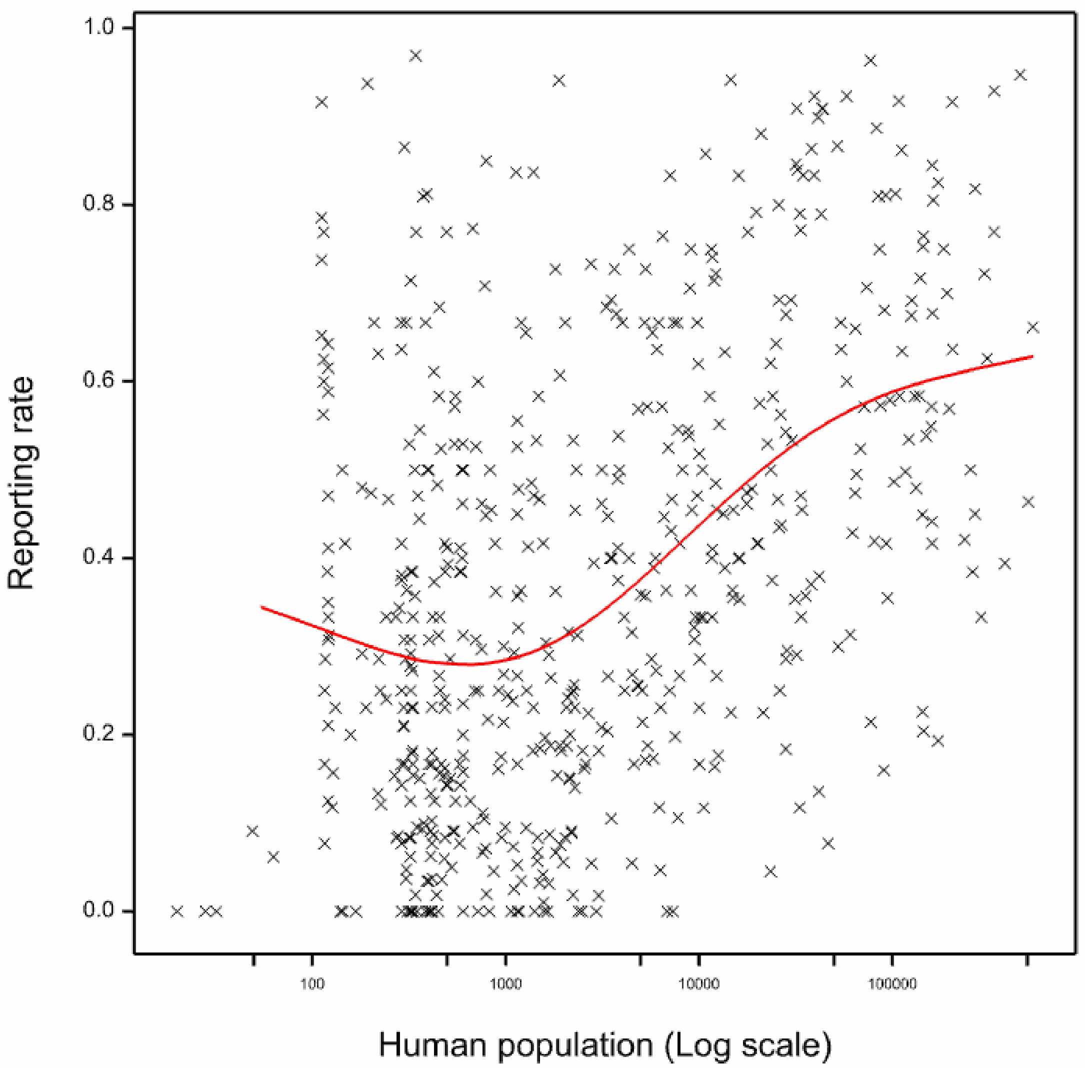

Fig. 6.12: The relationship between reporting rate of the House Sparrow (representing bird species in Group 10) and log of the human population in Greater Gauteng.

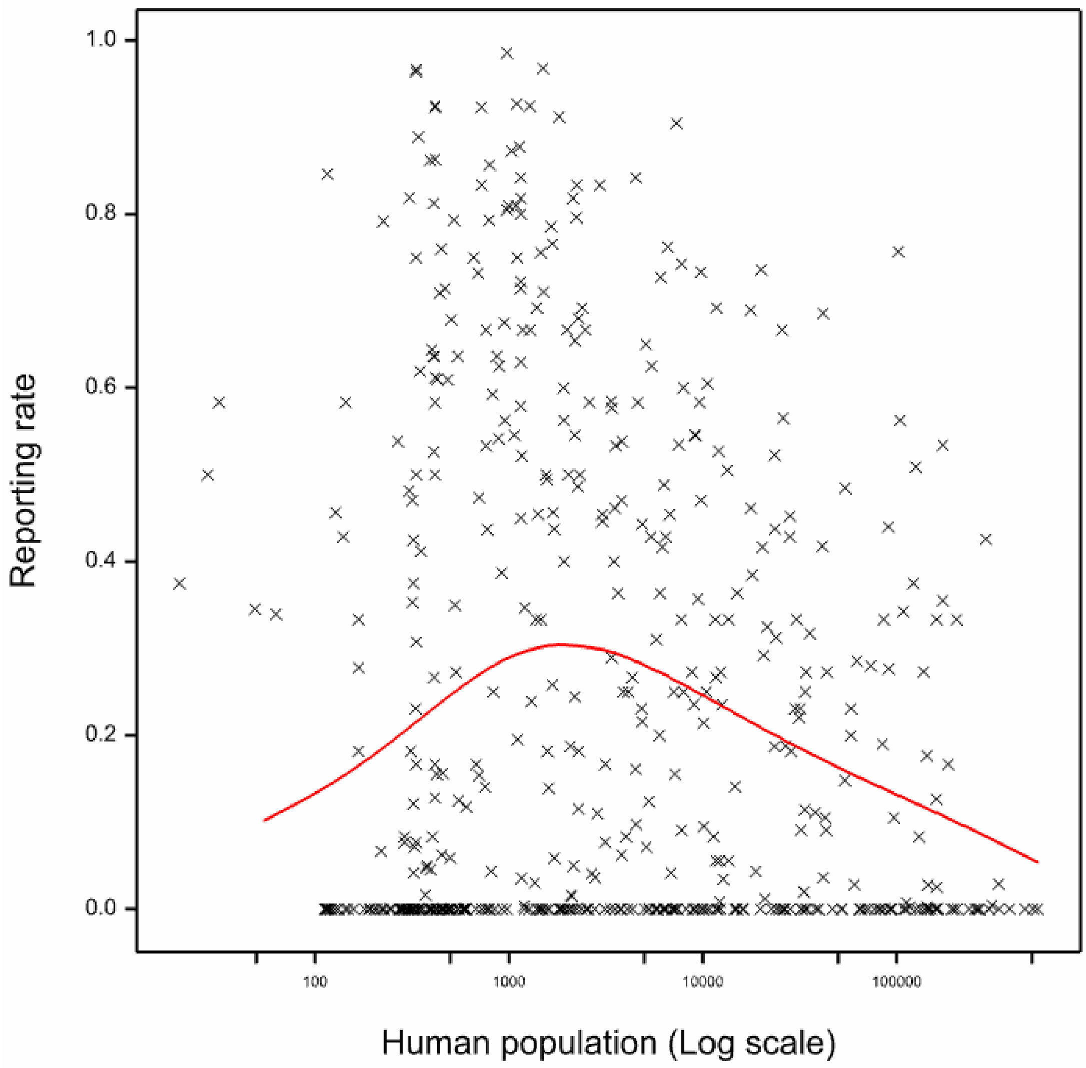

Fig. 6.13: The relationship between reporting rate of the Arrow-marked babbler (representing bird species in Group 11) and log of the human population in Greater Gauteng.

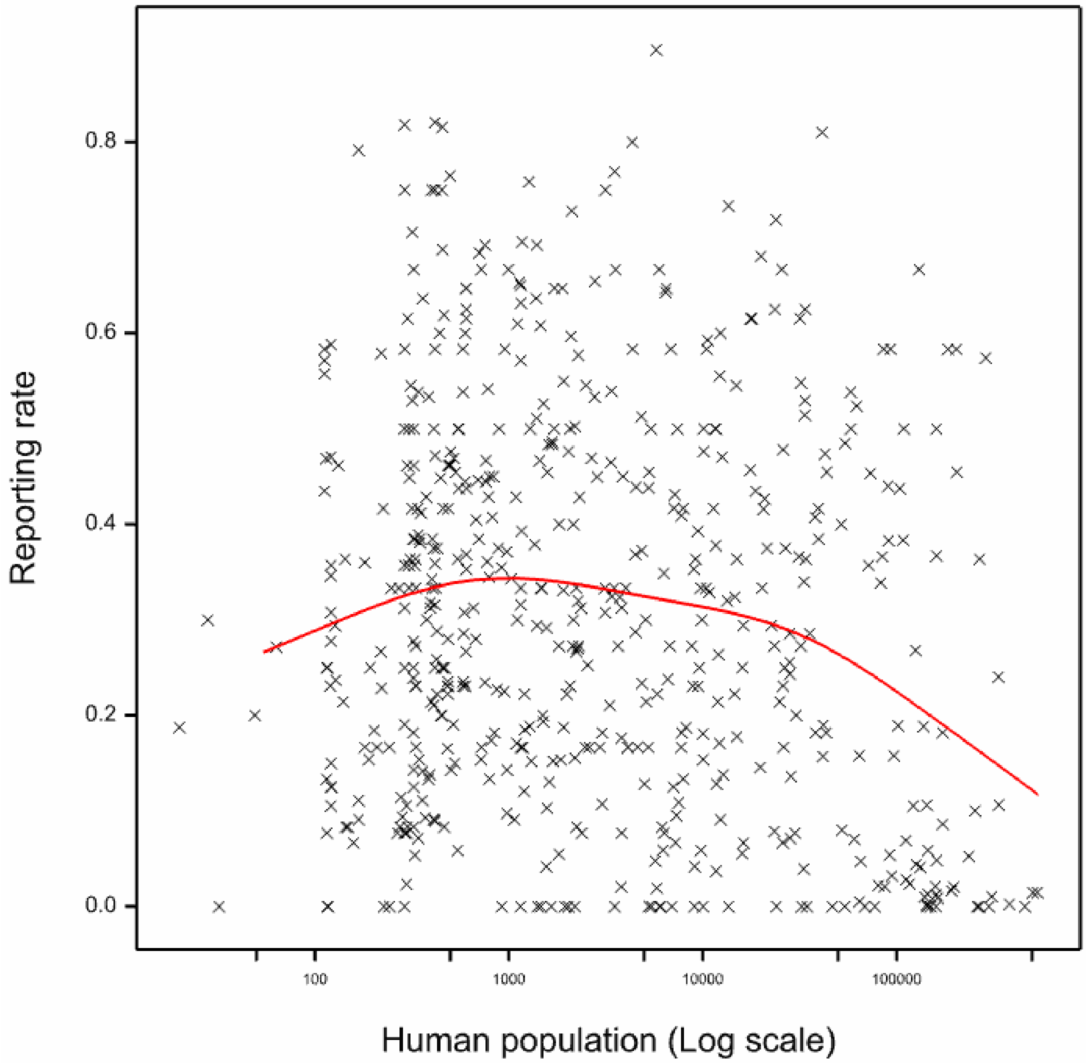

Fig. 6.14: The relationship between reporting rate of the White–winged Widowbird (representing bird species in Group 12) and log of the human population in Greater Gauteng.

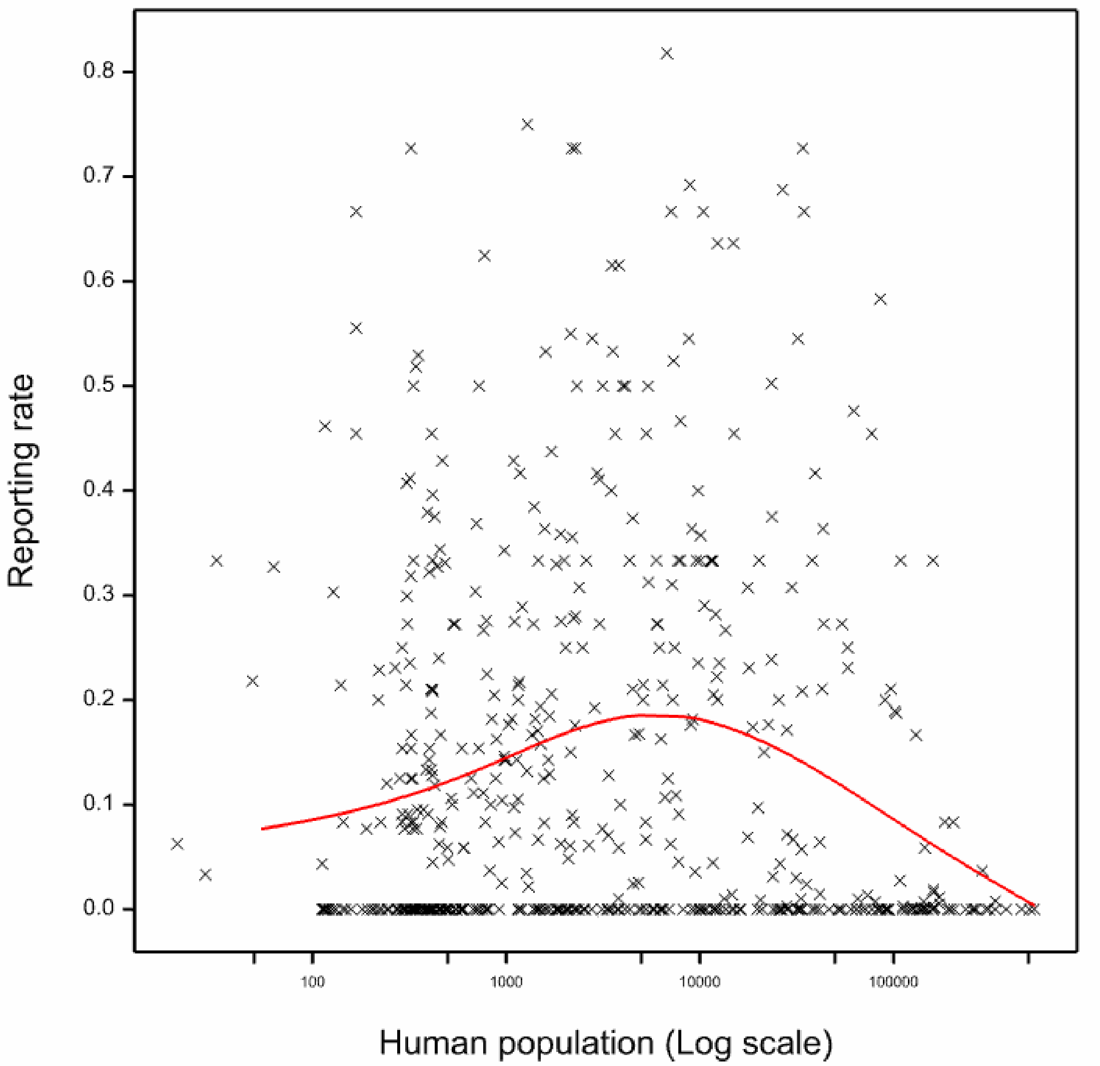

Fig. 6.15: The relationship between reporting rate of the Red-breasted Swallow (representing bird species in Group 13) and log of the human population in Greater Gauteng.

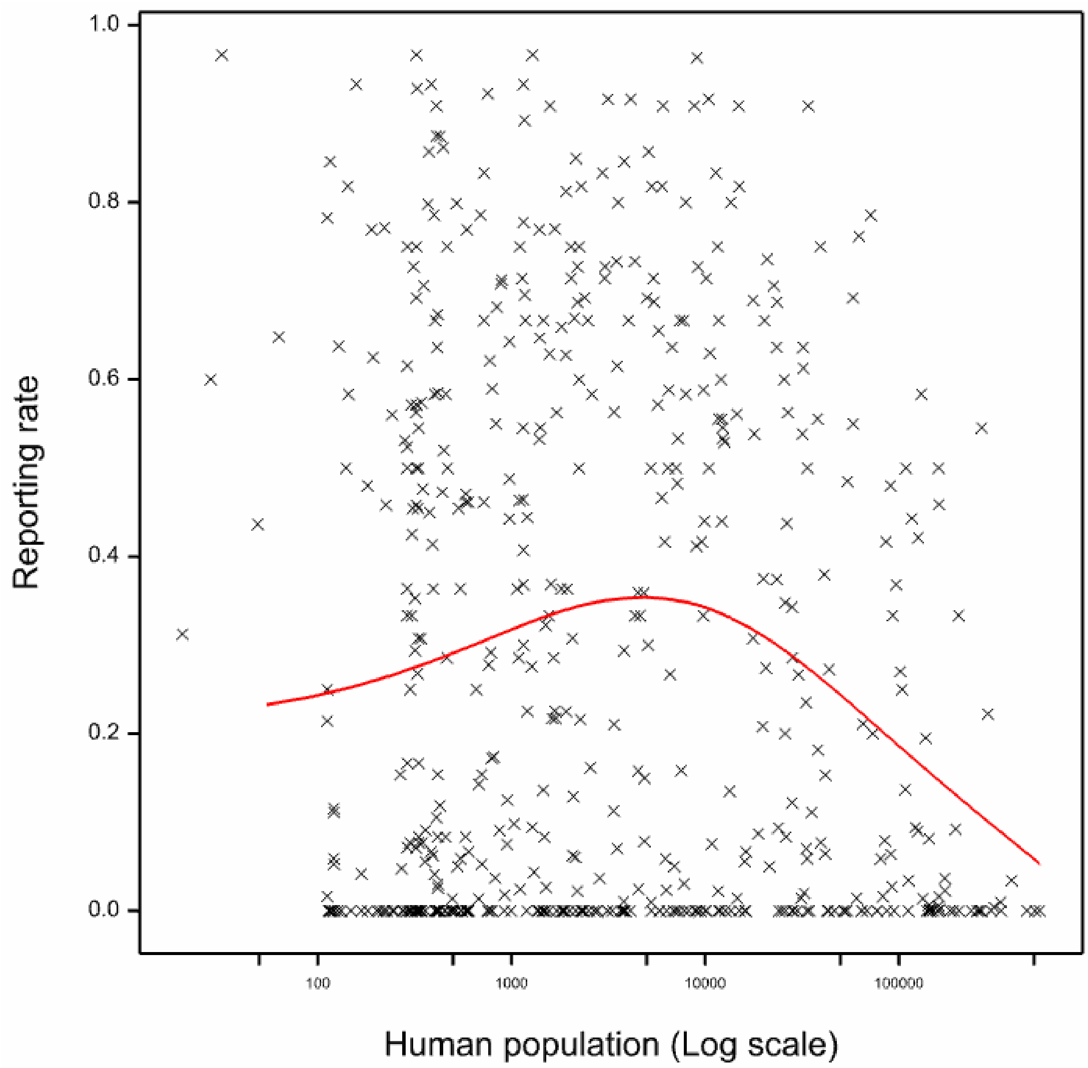

Fig. 6.16: The relationship between reporting rate of the Chestnut–vented Tit–babbler (representing bird species in Group 14) and log of the human population in Greater Gauteng.

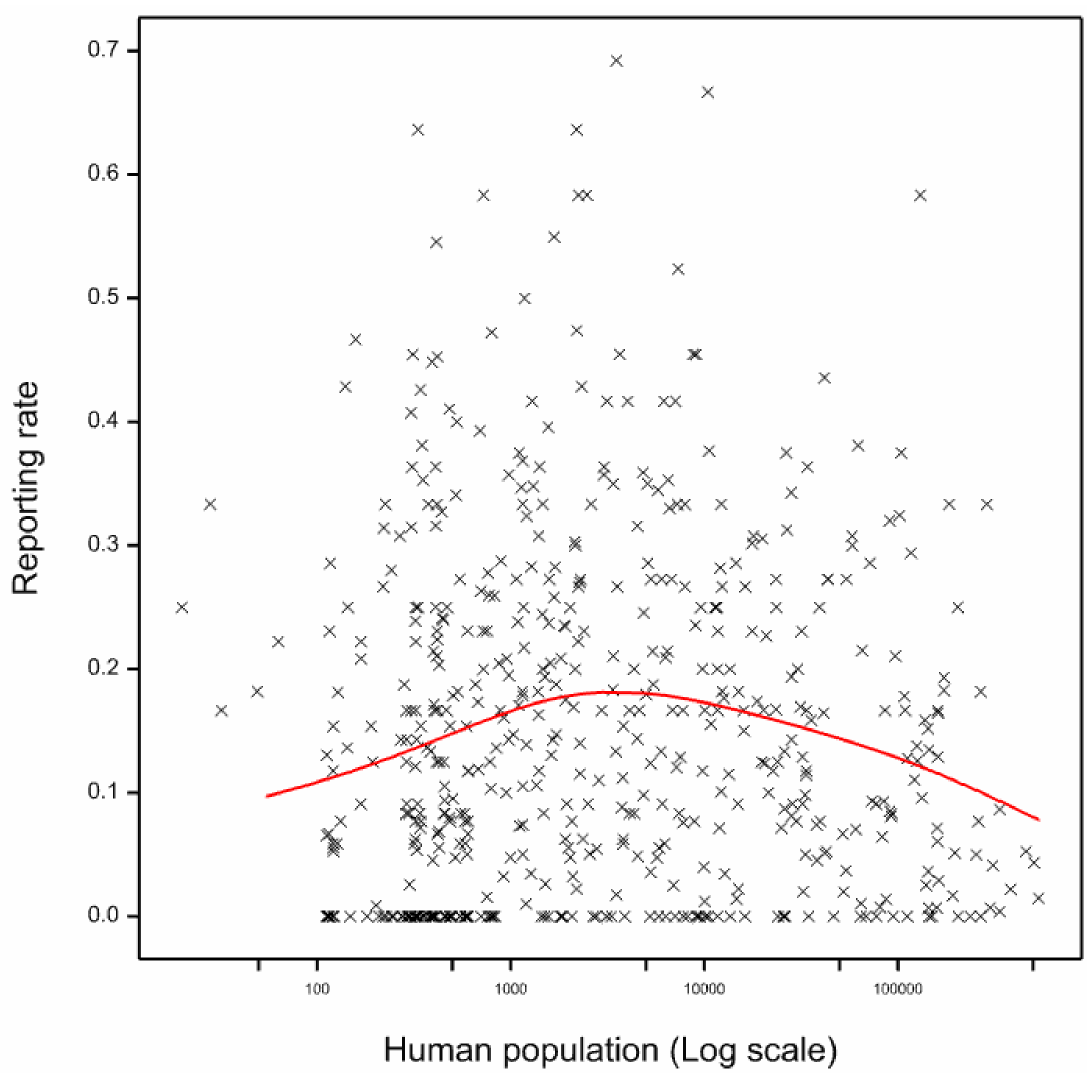

Fig. 6.17: The relationship between reporting rate of the Spotted Flycatcher (representing bird species in Group 15) and log of the human population in Greater Gauteng.

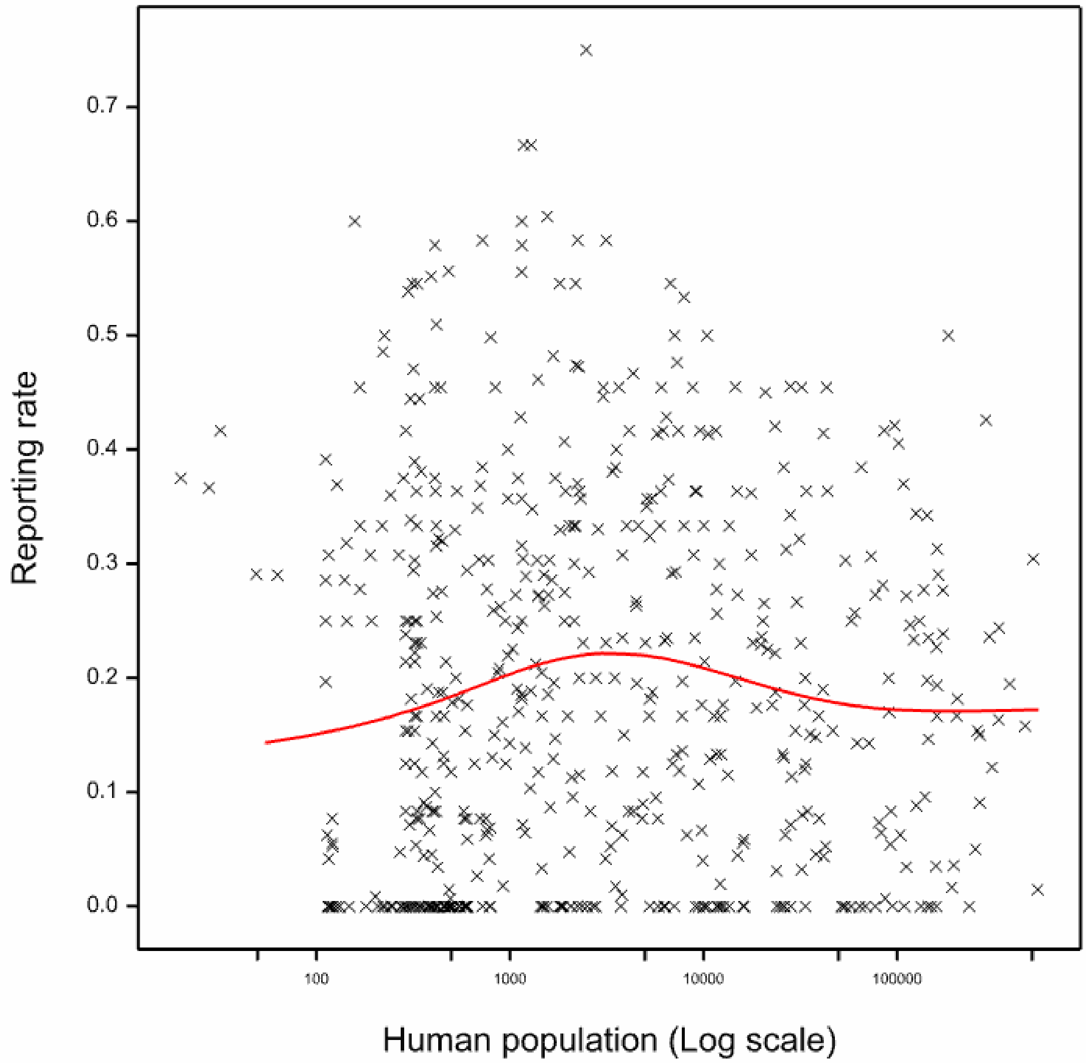

Fig. 6.18: The relationship between reporting rate of the European Bee–eater (representing bird species in Group 16) and log of the human population in Greater Gauteng.

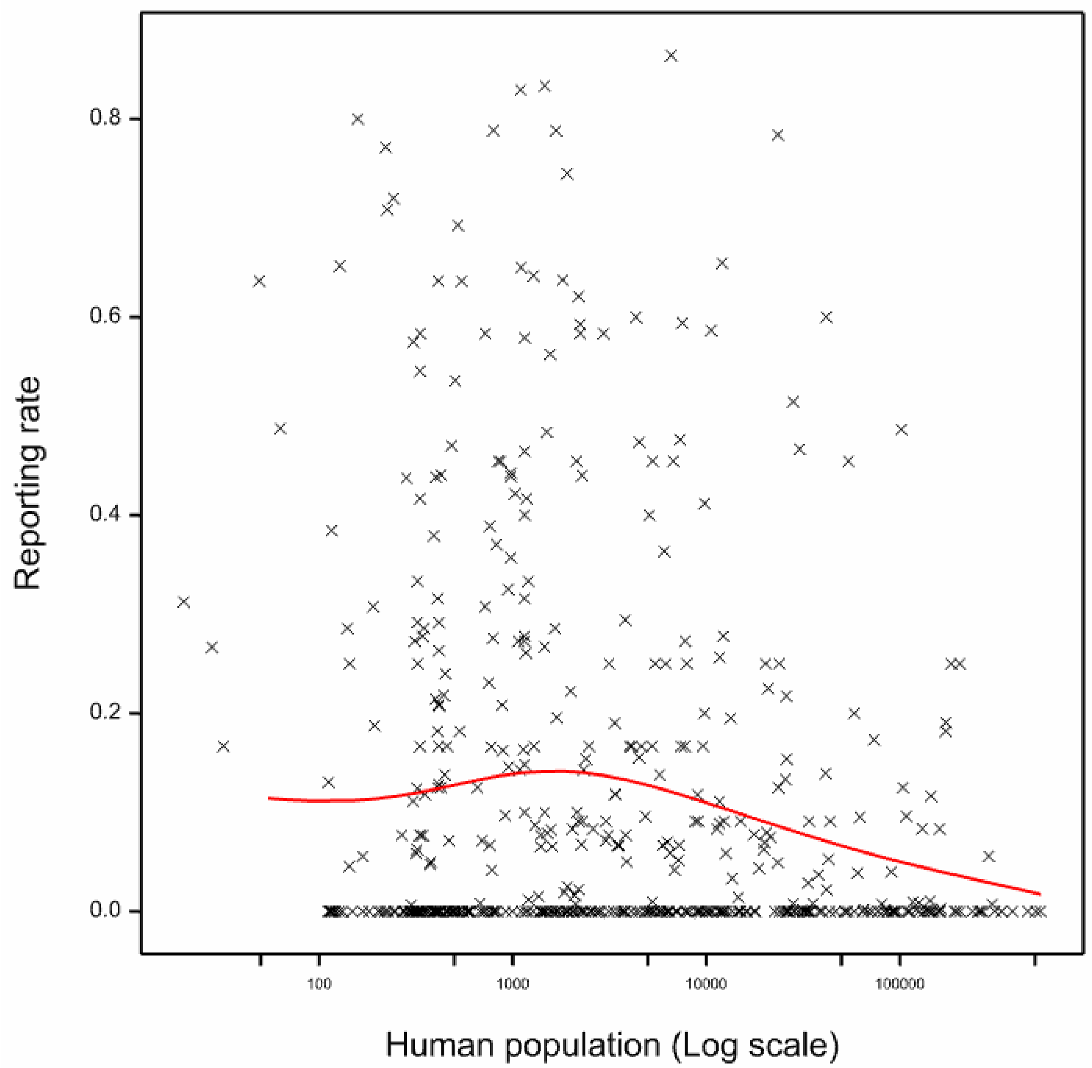

Fig. 6.19: The relationship between reporting rate of the Natal Spurfowl (representing bird species in Group 17) and log of the human population in Greater Gauteng.

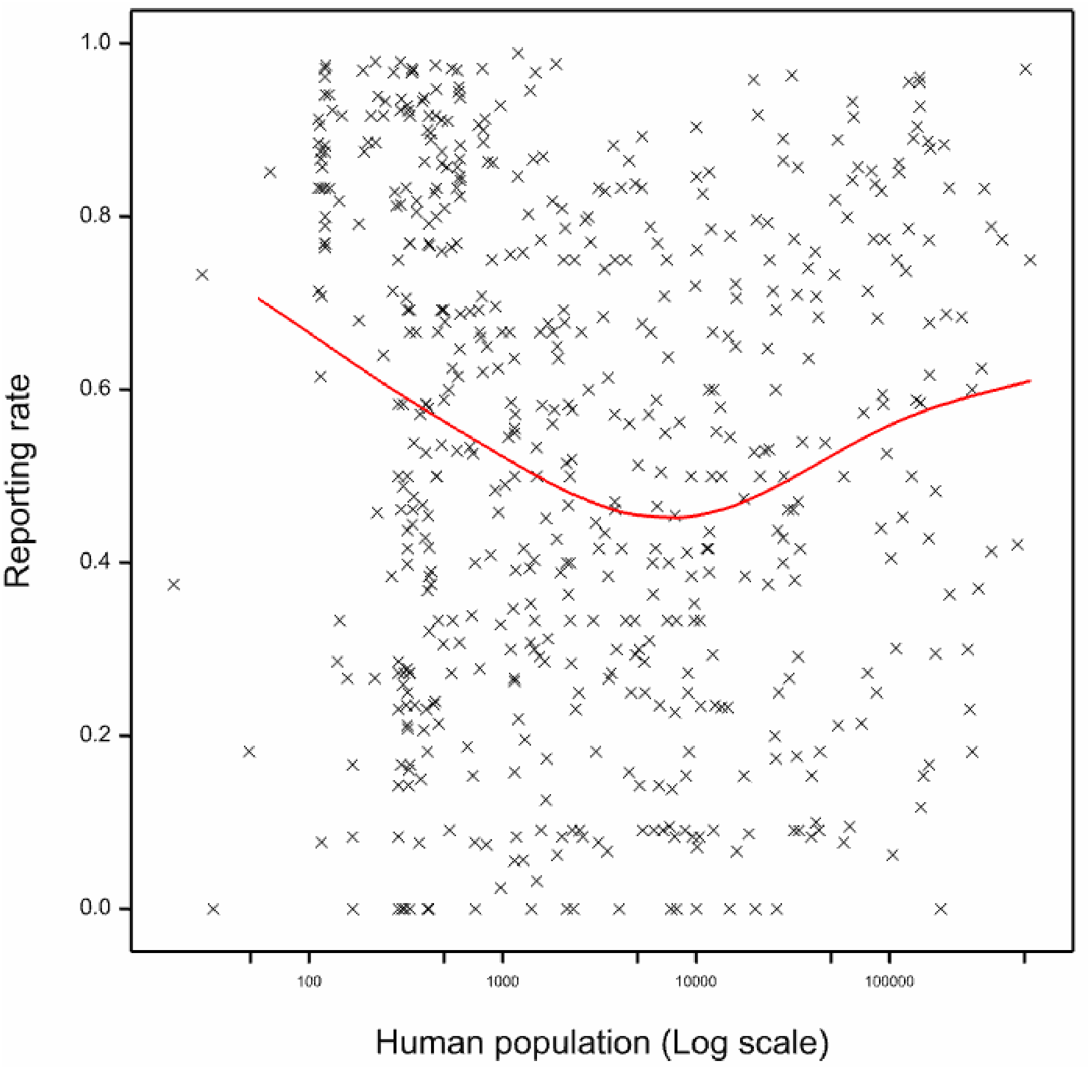

Fig. 6.20: The relationship between reporting rate of the Egyptian Goose (representing bird species in Group 18) and log of the human population in Greater Gauteng.

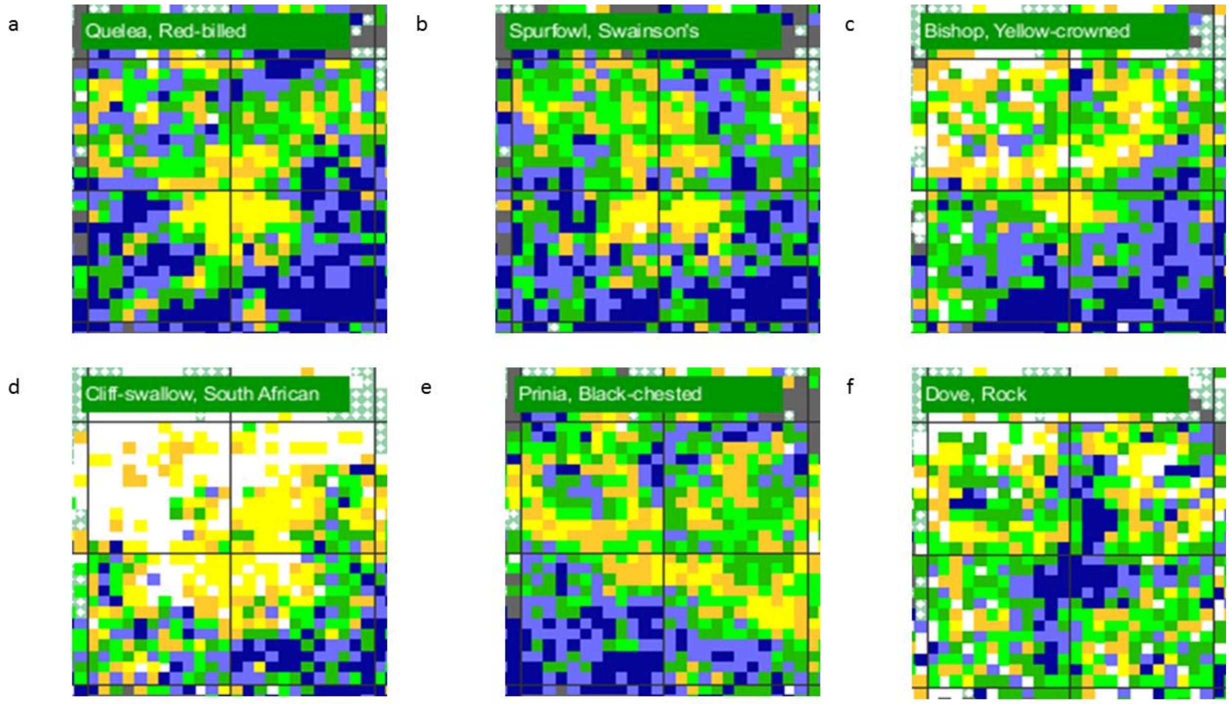

Plate 6.1: Geographic distribution pattern of group representative bird species in Greater Gauteng. a= Red-billed Quelea (Group 1), b= Swainsons Spurfowl (Group two), c= Yellow-crowned Bishop (Group three), d = African Cliff-swallow (Group four), e = Black-chested Prinia (Group five), f = Rock Dove (Group six) [Colour Legend: Blue=Large abundance and species richness, Yellow = Low abundance and species richness, Green = Medium abundance and species richness]

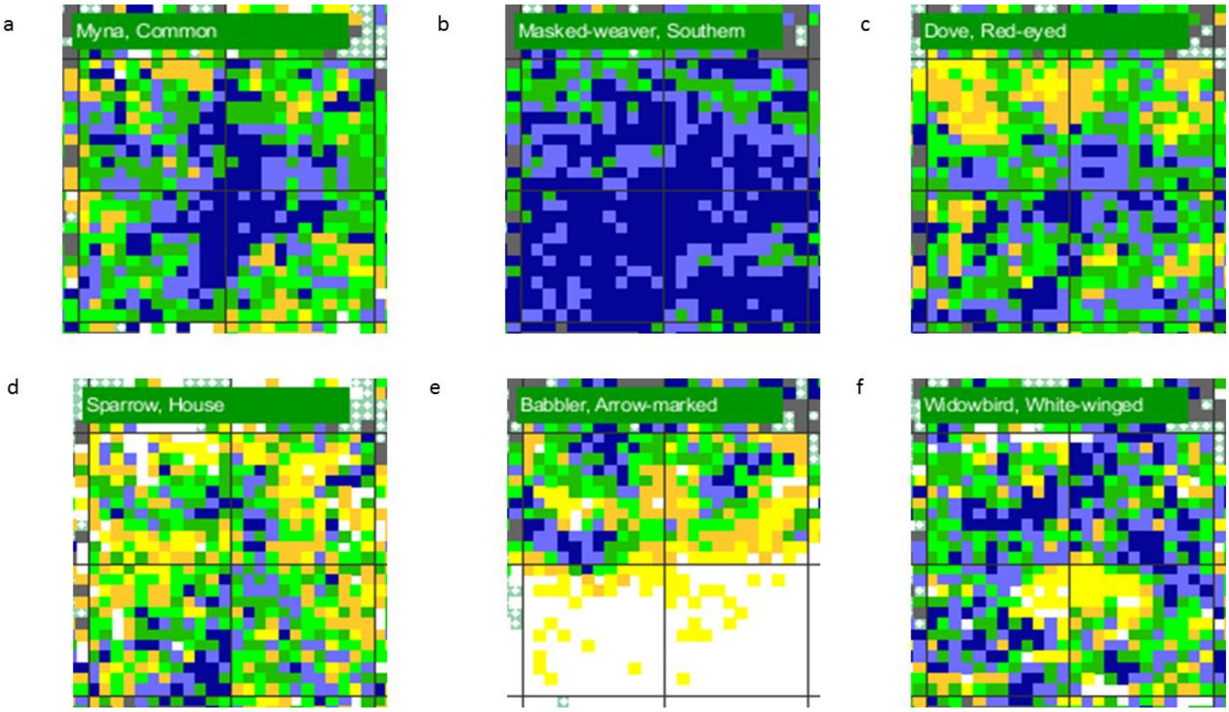

Plate 6.2: Geographic distribution pattern of group representative bird species in Greater Gauteng. a= Common Myna (Group 7), b= Southern Masked-weaver (Group Eight), c= Red-eyed Dove (Group Nine), d = House Sparrow (Group 10), e = Arrow marked Babbler (Group 11), f = White-winged widowbird (Group 12) [Colour Legend: Blue=Large abundance and species richness, Yellow = Low abundance and species richness, Green = Medium abundance and species richness]

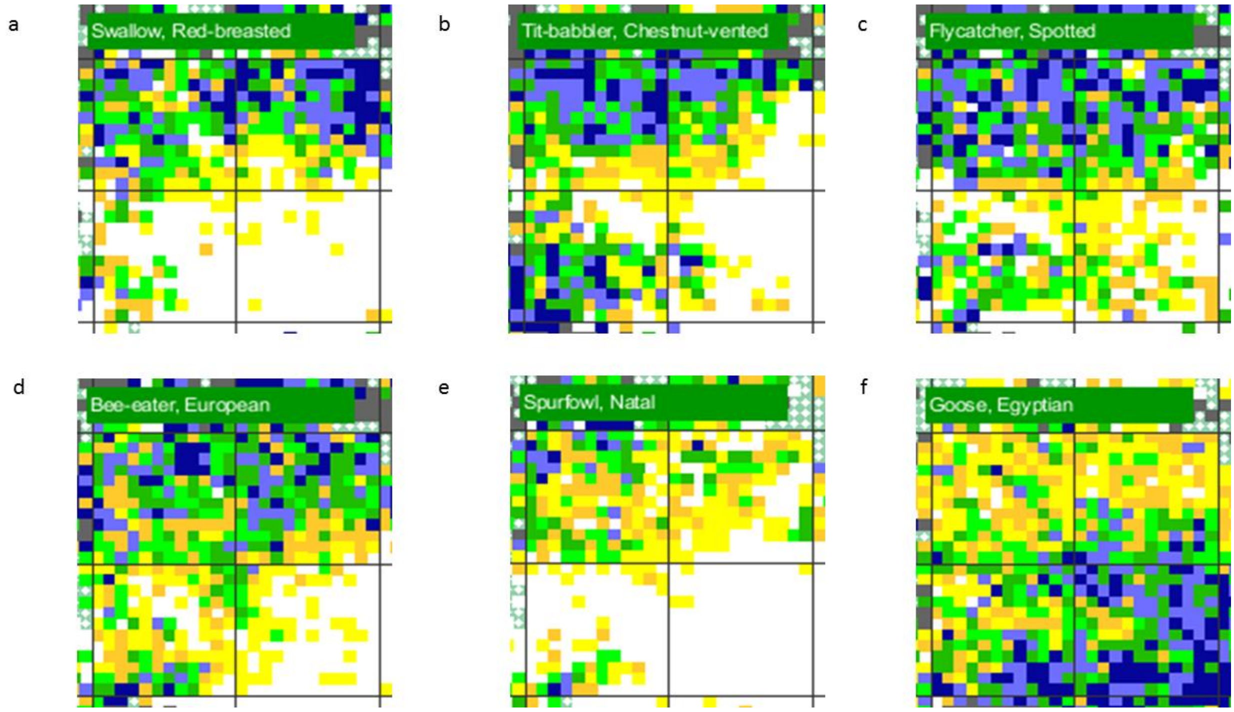

Plate 6.3: Geographic distribution pattern of group representative bird species in Greater Gauteng. a= Red-breasted Swallow (Group 13), b= Chestnut-vented Tit-babbler (Group 14), c= Spotted Flycatcher (Group 15), d = European Bee-eater (Group 16), e = Natal Spurfowl (Group 17), f = Egyptian Goose (Group 18) [Colour Legend: Blue=Large abundance and species richness, Yellow = Low abundance and species richness, Green = Medium abundance and species richness]

Table 6.1: Species in Group 1 and their range (number of pentads out of 576 total pentads) in Greater Gauteng.

S/No	Species Names	Number of Pentads
1	Common Ostrich	313
2	Great Egret	301
3	African Spoonbill	418
4	South African Shelduck	223
5	Rock Kestrel	200
6	Lesser Kestrel	175
7	African Fish-Eagle	288
8	Kittlitz's Plover	153
9	Namaqua Dove	455
10	White-backed Mousebird	208
11	Little Bee-eater	164
12	Banded Martin	278
13	African Red-eyed Bulbul	244
14	Yellow-throated Petronia	146
15	Red-billed Quelea	572
16	African Quailfinch	506

Table 6.2: Species in Group 2 and their ranges (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Names	Number of Pentads
1	Goliath Heron	244
2	Yellow-billed Egret	292
3	Amur Falcon	477
4	Steppe Buzzard	489
5	Swainson's Spurfowl	572
6	Common Greenshank	248
7	White-winged Tern	192
8	Whiskered Tern	320
9	Barn Owl	218
10	Acacia Pied Barbet	387
11	Common House-Martin	302
12	White-browed Sparrow-Weaver	453
13	Cinnamon-breasted Bunting	410

Table 6.3: Avian species in Group 3 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Name	Number of Pentads
1	Spur-winged Goose	483
2	Cape Shoveler	283
3	Greater Kestrel	261
4	African Snipe	345
5	Marsh Owl	288
6	Spike-heeled Lark	249
7	Cloud Cisticola	390
8	Cape Longclaw	450
9	Yellow-crowned Bishop	514
10	Long-tailed Widowbird	447
11	Northern Black Korhaan	421
12	Eastern Clapper Lark	242

Table 6.4: Species in Group 4 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No.	Species Name	Number of pentads
1	Secretarybird	182
2	Orange River Francolin	179
3	Common Quail	196
4	Chestnut-backed Sparrowlark	171
5	Red-capped Lark	333
6	South African Cliff-Swallow	388
7	Anteating Chat	336
8	Yellow Canary	352

Table 6.5: Avian species in Group 5 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Name	Number of Pentads
1	White-breasted Cormorant	408
2	Reed Cormorant	529
3	African Darter	421
4	Grey Heron	505
5	Little Egret	431
6	Yellow-billed Duck	520
7	Red-billed Teal	488
8	Southern Pochard	312
9	Black-shouldered Kite	570
10	Helmeted Guinea fowl	572
11	Three-banded Plover	474
12	Black-winged Stilt	309
13	Giant Kingfisher	262
14	Malachite Kingfisher	337
15	Rufous-naped Lark	544
16	African Stonechat	507
17	Zitting Cisticola	567
18	Wailing Cisticola	179
19	Levaillant's Cisticola	498
20	Black-chested Prinia	574
21	African Pipit	558
22	Plain-backed Pipit	207
23	Bokmakierie	385
24	Wattled Starling	416
25	Pin-tailed Whydah	562
26	Black-throated Canary	572

Table 6.6: Species in Group 6 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Name	Number of pentad**s**
1	Ovambo Sparrowhawk	146
2	Grey-headed Gull	241
3	Rock Martin	290
4	Little Rush-Warbler	291
5	Thick-billed Weaver	257
6	Bronze Mannikin	215
7	Rock Dove	507
8	Karoo Thrush	404

Table 6.7: Species in Group 7 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Names	Number of pentads
1	Purple Heron	356
2	Green-backed Heron	237
3	Black Heron	192
4	Fulvous Duck	170
5	Yellow-billed Kite	196
6	Grey Go-away-bird	362
7	Red-faced Mousebird	524
8	Green Wood-Hoopoe	481
9	Crested Barbet	545
10	Lesser Honeyguide	293
11	Pied Crow	505
12	Dark-capped Bulbul	522
13	Great Reed-Warbler	164
14	Tawny-flanked Prinia	490
15	Common Myna	574
16	Amethyst Sunbird	375

Table 6.8: Species in Group 8 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species name	Number of pentads
1	Little Grebe	526
2	Cattle Egret	573
3	White-faced Duck	514
4	Crowned Lapwing	574
5	Blacksmith Lapwing	574
6	Wood Sandpiper	318
7	Speckled Pigeon	569
8	Cape Turtle-Dove	575
9	Laughing Dove	576
10	Diderick Cuckoo	571
11	Little Swift	546
12	Barn Swallow	576
13	Brown-throated Martin	452
14	Capped Wheatear	358
15	Bar-throated Apalis	279
16	Wing-snapping Cisticola	265
17	Fairy Flycatcher	149
18	Long-billed Pipit	171
19	Cape Glossy Starling	573
20	Southern Masked-Weaver	576
21	Red-collared Widowbird	381
22	Common Waxbill	531

Table 6.9: Species in Group 9 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Name	Number of pentads
1	Glossy Ibis	437
2	Hadeda Ibis	572
3	Red-knobbed Coot	497
4	Pied Avocet	161
5	Red-eyed Dove	576
6	White-rumped Swift	562
7	Black-collared Barbet	514
8	Red-throated Wryneck	317
9	White-throated Swallow	511
10	Greater Striped Swallow	567
11	Mountain Wheatear	223
12	Fiscal Flycatcher	468
13	Cape Wagtail	523
14	Common Fiscal	553
15	Cape Sparrow	565
16	Southern Red Bishop	548

Table 6.10: Species in Group 10 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Name	Number of Pentads
1	Great Crested Grebe	179
2	Black-crowned Night-Heron	218
3	African Sacred Ibis	480
4	African Black Duck	337
5	African Purple Swamphen	246
6	Common Moorhen	459
7	African Wattled Lapwing	495
8	Spotted Thick-knee	434
9	Spotted Eagle-Owl	175
10	African Palm-Swift	487
11	Speckled Mousebird	499
12	African Hoopoe	454
13	Cape Robin-Chat	462
14	Lesser Swamp-Warbler	407
15	African Reed-Warbler	297
16	Marsh Warbler	184
17	Red-winged Starling	273
18	Pied Starling	314
19	House Sparrow	540
20	Red-headed Finch	358
21	Orange-breasted Waxbill	266
22	Streaky-headed Seedeater	343
23	Cape White-eye	485

Table 6.11: Species in Group 11 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species names	Number of pentads
1	Crested Francolin	248
2	African Jacana	195
3	Black Cuckoo	208
4	Levaillant's Cuckoo	166
5	Woodland Kingfisher	227
6	African Grey Hornbill	297
7	Yellow-fronted Tinkerbird	225
8	Golden-tailed Woodpecker	244
9	Black-headed Oriole	285
10	Arrow-marked Babbler	318
11	Groundscraper Thrush	297
12	Cape Grassbird	161
13	Grey-headed Bush-Shrike	186
14	Village Indigobird	166

Table 6.12: Species in Group 12 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Names	Number of pentads
1	Hamerkop	411
2	White-backed Duck	145
3	Common Sandpiper	201
4	Marsh Sandpiper	145
5	Common Swift	170
6	Pied Kingfisher	401
7	Familiar Chat	268
8	Desert Cisticola	399
9	Neddicky	533
10	Buffy Pipit	181
11	White-winged Widowbird	537

Table 6.13: Species in Group 13 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Name	Number of pentads
1	Gabar Goshawk	199
2	Lilac-breasted Roller	222
3	Southern Yellow-billed Hornbill	180
4	Sabota Lark	231
5	Pearl-breasted Swallow	271
6	Red-breasted Swallow	321
7	Fork-tailed Drongo	315
8	White-throated Robin-Chat	228
9	White-browed Scrub-Robin	267
10	Burnt-necked Eremomela	164
11	Long-billed Crombec	300
12	Rattling Cisticola	314
13	Marico Flycatcher	215
14	Crimson-breasted Shrike	303
15	Magpie Shrike	198
16	Marico Sunbird	188
17	Scaly-feathered Finch	237
18	Red-billed Firefinch	233
19	Blue Waxbill	367
20	Shaft-tailed Whydah	157

Table 6.14: Species in Group 14 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species names	Number of pentads
1	Lanner Falcon	170
2	Black-chested Snake-Eagle	280
3	Kalahari Scrub-Robin	284
4	Chestnut-vented Tit-Babbler	393
5	Chinspot Batis	339
6	Lesser Grey Shrike	346
7	Red-backed Shrike	432
8	Brown-crowned Tchagra	358
9	Green-winged Pytilia	275
10	Violet-eared Waxbill	193
11	Black-faced Waxbill	162
12	Long-tailed Paradise-Whydah	251
13	Golden-breasted Bunting	260

Table 6.15: Species in Group 15 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Names	Number of pentads
1	Red-chested Cuckoo	407
2	Klaas's Cuckoo	188
3	Brown-hooded Kingfisher	317
4	White-fronted Bee-eater	272
5	Lesser Striped Swallow	356
6	Kurrichane Thrush	264
7	Spotted Flycatcher	452
8	Southern Boubou	343
9	Black-crowned Tchagra	247
10	White-bellied Sunbird	417
11	Village Weaver	225
12	Cape Weaver	247
13	Jameson's Firefinch	264
14	Yellow-fronted Canary	412

Table 6.16: Species in Group 16 and their range (number of pentads out of 576 total pentads) in the Greater Gauteng

S/No	Species Names	Number of pentads
1	Squacco Heron	286
2	Black Crake	316
3	African Black Swift	178
4	Horus Swift	160
5	European Bee-eater	444
6	Greater Honeyguide	244
7	Cardinal Woodpecker	337
8	Willow Warbler	409
9	Lazy Cisticola	157
10	African Paradise-Flycatcher	361
11	Black-backed Puffback	251

Table 6.17: Species in Group 17 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Names	Number of pentads
1	Comb Duck	146
2	Brown Snake-Eagle	165
3	Coqui Francolin	229
4	Natal Spurfowl	263
5	Jacobin Cuckoo	181
6	Pearl-spotted Owlet	182
7	Black Cuckooshrike	157
8	Southern Black Tit	147
9	Grey-backed Camaroptera	205
10	Southern Black Flycatcher	189
11	Orange-breasted Bush-Shrike	172
12	Brubru	259
13	Violet-backed Starling	190

Table 6.18: Species in Group 18 and their range (number of pentads out of 576 total pentads) in Greater Gauteng

S/No	Species Names	Number of pentads
1	Black-headed Heron	551
2	White Stork	222
3	Greater Flamingo	174
4	Egyptian Goose	555
5	Cape Teal	150
6	Little Stint	185
7	Ruff	212

Appendix 6.1: Bird species that occurred in at least a quarter (144) of the total pentads (576) that make up Greater Gauteng.

S/No	Species common names	Group	Species' occurrence range in Greater Gauteng (Number of Pentads)
1	White-breasted Cormorant	1	408
2	Reed Cormorant	1	529
3	African Darter	1	421
4	Grey Heron	1	505
5	Little Egret	1	431
6	Yellow-billed Duck	1	520
7	Red-billed Teal	1	488
8	Southern Pochard	1	312
9	Black-shouldered Kite	1	570
10	Helmeted Guineafowl	1	572
11	Three-banded Plover	1	474
12	Black-winged Stilt	1	309
13	Giant Kingfisher	1	262
14	Malachite Kingfisher	1	337
15	Rufous-naped Lark	1	544
16	African Stonechat	1	507
17	Zitting Cisticola	1	567
18	Wailing Cisticola	1	179
19	Levaillant's Cisticola	1	498
20	Black-chested Prinia	1	574
21	African Pipit	1	558
22	Plain-backed Pipit	1	207
23	Bokmakierie	1	385
24	Wattled Starling	1	416
25	Pin-tailed Whydah	1	562
26	Black-throated Canary	1	572
27	Spur-winged Goose	2	483
28	Cape Shoveler	2	283
29	Greater Kestrel	2	261
30	African Snipe	2	345
31	Marsh Owl	2	288
32	Spike-heeled Lark	2	249
33	Cloud Cisticola	2	390
34	Cape Longclaw	2	450
35	Yellow-crowned Bishop	2	514
36	Long-tailed Widowbird	2	447
37	Northern Black Korhaan	2	421
38	Eastern Clapper Lark	2	242
39	Secretarybird	3	182
40	Orange River Francolin	3	179
41	Common Quail	3	196
42	Chestnut-backed Sparrowlark	3	171
43	Red-capped Lark	3	333
44	South African Cliff-Swallow	3	388
45	Anteating Chat	3	336
46	Yellow Canary	3	352
47	Common Ostrich	4	313
48	Great Egret	4	301
49	African Spoonbill	4	418

S/No	Species common names	Group	Species' occurrence range in Greater Gauteng (Number of Pentads)
50	South African Shelduck	4	223
51	Rock Kestrel	4	200
52	Lesser Kestrel	4	175
53	African Fish-Eagle	4	288
54	Kittlitz's Plover	4	153
55	Namaqua Dove	4	455
56	White-backed Mousebird	4	208
57	Little Bee-eater	4	164
58	Banded Martin	4	278
59	African Red-eyed Bulbul	4	244
60	Yellow-throated Petronia	4	146
61	Red-billed Quelea	4	572
62	African Quailfinch	4	506
63	Glossy Ibis	5	437
64	Hadeda Ibis	5	572
65	Red-knobbed Coot	5	497
66	Pied Avocet	5	161
67	Red-eyed Dove	5	576
68	White-rumped Swift	5	562
69	Black-collared Barbet	5	514
70	Red-throated Wryneck	5	317
71	White-throated Swallow	5	511
72	Greater Striped Swallow	5	567
73	Mountain Wheatear	5	223
74	Fiscal Flycatcher	5	468
75	Cape Wagtail	5	523
76	Common Fiscal	5	553
77	Cape Sparrow	5	565
78	Southern Red Bishop	5	548
79	Great Crested Grebe	6	179
80	Black-crowned Night-Heron	6	218
81	African Sacred Ibis	6	480
82	African Black Duck	6	337
83	African Purple Swamphen	6	246
84	Common Moorhen	6	459
85	African Wattled Lapwing	6	495
86	Spotted Thick-knee	6	434
87	Spotted Eagle-Owl	6	175
88	African Palm-Swift	6	487
89	Speckled Mousebird	6	499
90	African Hoopoe	6	454
91	Cape Robin-Chat	6	462
92	Lesser Swamp-Warbler	6	407
93	African Reed-Warbler	6	297
94	Marsh Warbler	6	184
95	Red-winged Starling	6	273
96	Pied Starling	6	314
97	House Sparrow	6	540
98	Red-headed Finch	6	358
99	Orange-breasted Waxbill	6	266
100	Streaky-headed Seedeater	6	343
101	Cape White-eye	6	485

S/No	Species common names	Group	Species' occurrence range in Greater Gauteng (Number of Pentads)
102	Ovambo Sparrowhawk	7	146
103	Grey-headed Gull	7	241
104	Rock Martin	7	290
105	Little Rush-Warbler	7	291
106	Thick-billed Weaver	7	257
107	Bronze Mannikin	7	215
108	Rock Dove	7	507
109	Karoo Thrush	7	404
110	Gabar Goshawk	8	199
111	Lilac-breasted Roller	8	222
112	Southern Yellow-billed Hornbill	8	180
113	Sabota Lark	8	231
114	Pearl-breasted Swallow	8	271
115	Red-breasted Swallow	8	321
116	Fork-tailed Drongo	8	315
117	White-throated Robin-Chat	8	228
118	White-browed Scrub-Robin	8	267
119	Burnt-necked Eremomela	8	164
120	Long-billed Crombec	8	300
121	Rattling Cisticola	8	314
122	Marico Flycatcher	8	215
123	Crimson-breasted Shrike	8	303
124	Magpie Shrike	8	198
125	Marico Sunbird	8	188
126	Scaly-feathered Finch	8	237
127	Red-billed Firefinch	8	233
128	Blue Waxbill	8	367
129	Shaft-tailed Whydah	8	157
130	Goliath Heron	9	244
131	Yellow-billed Egret	9	292
132	Amur Falcon	9	477
133	Steppe Buzzard	9	489
134	Swainson's Spurfowl	9	572
135	Common Greenshank	9	248
136	White-winged Tern	9	192
137	Whiskered Tern	9	320
138	Barn Owl	9	218
139	Acacia Pied Barbet	9	387
140	Common House-Martin	9	302
141	White-browed Sparrow-Weaver	9	453
142	Cinnamon-breasted Bunting	9	410
143	Comb Duck	10	146
144	Brown Snake-Eagle	10	165
145	Coqui Francolin	10	229
146	Natal Spurfowl	10	263
147	Jacobin Cuckoo	10	181
148	Pearl-spotted Owlet	10	182
149	Black Cuckooshrike	10	157
150	Southern Black Tit	10	147
151	Grey-backed Camaroptera	10	205

S/No	Species common names	Group	Species' occurrence range in Greater Gauteng (Number of Pentads)
152	Southern Black Flycatcher	10	189
153	Orange-breasted Bush-Shrike	10	172
154	Brubru	10	259
155	Violet-backed Starling	10	190
156	Squacco Heron	11	286
157	Black Crake	11	316
158	African Black Swift	11	178
159	Horus Swift	11	160
160	European Bee-eater	11	444
161	Greater Honeyguide	11	244
162	Cardinal Woodpecker	11	337
163	Willow Warbler	11	409
164	Lazy Cisticola	11	157
165	African Paradise-Flycatcher	11	361
166	Black-backed Puffback	11	251
167	Purple Heron	12	356
168	Green-backed Heron	12	237
169	Black Heron	12	192
170	Fulvous Duck	12	170
171	Yellow-billed Kite	12	196
172	Grey Go-away-bird	12	362
173	Red-faced Mousebird	12	524
174	Green Wood-Hoopoe	12	481
175	Crested Barbet	12	545
176	Lesser Honeyguide	12	293
177	Pied Crow	12	505
178	Dark-capped Bulbul	12	522
179	Great Reed-Warbler	12	164
180	Tawny-flanked Prinia	12	490
181	Common Myna	12	574
182	Amethyst Sunbird	12	375
183	Lanner Falcon	13	170
184	Black-chested Snake-Eagle	13	280
185	Kalahari Scrub-Robin	13	284
186	Chestnut-vented Tit-Babbler	13	393
187	Chinspot Batis	13	339
188	Lesser Grey Shrike	13	346
189	Red-backed Shrike	13	432
190	Brown-crowned Tchagra	13	358
191	Green-winged Pytilia	13	275
192	Violet-eared Waxbill	13	193
193	Black-faced Waxbill	13	162
194	Long-tailed Paradise-Whydah	13	251
195	Golden-breasted Bunting	13	260
196	Hamerkop Hamerkop	14	411
197	White-backed Duck	14	145
198	Common Sandpiper	14	201
199	Marsh Sandpiper	14	145
200	Common Swift	14	170
201	Pied Kingfisher	14	401
202	Familiar Chat	14	268
203	Desert Cisticola	14	399

S/No	Species common names	Group	Species' occurrence range in Greater Gauteng (Number of Pentads)
204	Neddicky Neddicky	14	533
205	Buffy Pipit	14	181
206	White-winged Widowbird	14	537
207	Crested Francolin	15	248
208	African Jacana	15	195
209	Black Cuckoo	15	208
210	Levaillant's Cuckoo	15	166
211	Woodland Kingfisher	15	227
212	African Grey Hornbill	15	297
213	Yellow-fronted Tinkerbird	15	225
214	Golden-tailed Woodpecker	15	244
215	Black-headed Oriole	15	285
216	Arrow-marked Babbler	15	318
217	Groundscraper Thrush	15	297
218	Cape Grassbird	15	161
219	Grey-headed Bush-Shrike	15	186
220	Village Indigobird	15	166
221	Little Grebe	16	526
222	Cattle Egret	16	573
223	White-faced Duck	16	514
224	Crowned Lapwing	16	574
225	Blacksmith Lapwing	16	574
226	Wood Sandpiper	16	318
227	Speckled Pigeon	16	569
228	Cape Turtle-Dove	16	575
229	Laughing Dove	16	576
230	Diderick Cuckoo	16	571
231	Little Swift	16	546
232	Barn Swallow	16	576
233	Brown-throated Martin	16	452
234	Capped Wheatear	16	358
235	Bar-throated Apalis	16	279
236	Wing-snapping Cisticola	16	265
237	Fairy Flycatcher	16	149
238	Long-billed Pipit	16	171
239	Cape Glossy Starling	16	573
240	Southern Masked-Weaver	16	576
241	Red-collared Widowbird	16	381
242	Common Waxbill	16	531
243	Red-chested Cuckoo	17	407
244	Klaas's Cuckoo	17	188
245	Brown-hooded Kingfisher	17	317
246	White-fronted Bee-eater	17	272
247	Lesser Striped Swallow	17	356
248	Kurrichane Thrush	17	264
249	Spotted Flycatcher	17	452
250	Southern Boubou	17	343
251	Black-crowned Tchagra	17	247
252	White-bellied Sunbird	17	417
253	Village Weaver	17	225
254	Cape Weaver	17	247
255	Jameson's Firefinch	17	264

S/No	Species common names	Group	Species' occurrence range in Greater Gauteng (Number of Pentads)
256	Yellow-fronted Canary	17	412
257	Black-headed Heron	18	551
258	White Stork	18	222
259	Greater Flamingo	18	174
260	Egyptian Goose	18	555
261	Cape Teal	18	150
262	Little Stint	18	185
263	Ruff	18	212

Chapter Seven

Follow–the–Money Birds: Birds as indicators of spatial economic patterns in Greater Gauteng

Abstract

This chapter examines patterns between a socio-economic index, mean income per person, and the reporting rates of birds in Greater Gauteng. Bird atlas reporting rates in 144 pentads with human population in the upper quartile of the 576 pentads of Greater Gauteng were used. The mean income per person in each pentad was estimated from the 2011 census database. For the 144 pentads, reporting rates for the 263 bird species were plotted against the logarithm of mean income. A smoothed line of reporting rates was fitted through the scatterplot, based on 20 equally spaced points. There were strong relationships, displaying multiple patterns, between reporting rates of the birds and the mean incomes of the inhabitants. The 20 points along each of the 263 lines, one for each species, were assembled into a matrix with 263 rows and 20 columns, which was row-centred and then subjected to a covariance biplot. 89.3% of the information in the matrix was captured by the first two dimensions. The first dimension explained 72.8% of the information and therefore characterised the most feature of the data matrix. Examination of the scatterplots revealed that this dimension placed species along a continuum in response to income levels per pentad. The extremes of the continuum contained the bird species which strongly "follow-the-money" and those which strongly "follow-poverty". Species with a gradual trend in the strength of the relationship occur between these extremes, with the species that are "indifferent to poverty" in the middle of the continuum. The second dimension explained 16.5% of the information. It represented a contrast between species for which the overall response pattern to income was convex and those for which it was concave. A small number of species exhibited convex or concave patterns which showed peaks and valleys of reporting rate at intermediate income levels, respectively. Generally, the overall impact of increases in average income on the reporting rate of birds in Greater Gauteng was negative. 74 species showed increases in reporting rate with increases in income, while 114 species showed decreases. This chapter offers a new quantitative approach to the study of urban biodiversity. It demonstrated that the bird atlas data, in spite of the spatial limitation of the five-minute pentad scale, was able to demonstrate a relationship between bird reporting rates and a fundamental socio-economic metric, mean income level. The results suggest opportunities for further research to investigate the impact of socio-economic factors on bird species distributions.

Introduction

The Gini coefficient, used to measure income or wealth inequality, is a measure of statistical dispersion which represents the income or wealth distribution of a nation's residents, effectively a ratio between the richest and the poorest (Dorfman, 1979, Chen et al., 1982, Milanovic, 1997). South Africa has the worst Gini Index of any country for which this is calculated (Bosch et al., 2010, World Bank, 2014, World Bank group, 2015). Within Gauteng, the contrast between areas occupied by rich people and poor people, is extreme. For example, Sandton, the town between Johannesburg and Pretoria, is one of the most affluent parts of Africa, while the adjacent township, Alexandra, is characterized by extreme poverty (Nyapokoto, 2014). This is a classic example of what Massey (1996) described as a new world era of urban extremes in which rapid urbanization combined with rising levels of income inequality creates an 'ecology of inequality' or 'hyper–segregation' in urban centres. This phenomenon of segregation is also true of the urban sections within Gauteng, with rich suburbs adjacent to poor suburbs a common occurrence. An ecological outcome of such hyper–segregation is bound to be profound and of potential significance to biodiversity conservation in urban areas (Warren et al., 2010). Our understanding of these consequences is limited and presents a knowledge gap that needs to be addressed. While there has been a vast number of studies within the South African context which are similar to that of Nyapokoto (2014), describing and contrasting the human impact of poverty and wealth, there are remarkably few studies which attempt to describe the direct impacts of socio–politico–economic factors on biodiversity. One of these is Underhill et al. (2016), which contrasted the bird communities of a section of the Kruger National Park, who enjoys the highest conservation status in South Africa, with those of a region once known as Gazankulu, which was a self–governing state immediately adjacent to the Kruger National Park and characterized by overcrowding and poverty. While Underhill et al. (2016) was in a rural context, this chapter documents research in an urban one.

Many studies have contributed to our understanding of the relationship between avian biodiversity and habitat in urban areas; they have focused on the effect on birds of natural environmental factors such as green spaces in urban areas, spatial patterns and size of natural habitats in urban spaces (e.g. Donnelly and Marzluff, 1998, McKinney, 2002, Melles et al., 2003, Evans et al., 2009, Loss et al., 2009). Fewer studies have focused on non–environmental factors such as socioeconomic factors of urban residents as well as planning and structure of the towns associated with urban areas and how this influences biodiversity in urban spaces (Chase and Walsh, 2006, Mikkleson et al., 2007, Ortega-Alvarez and MacGregor-Fors, 2009, Loss et al., 2009).

The objectives of this chapter are two-fold: (1) To investigate whether the data collected by the Second Southern African Bird Atlas (SABAP2) reveals patterns between bird communities and an index of the human socio-economic context within which these bird communities live, and (2) To describe these patterns (but it is beyond the scope of this chapter to explain them in causal terms). In advance of the analysis, it is not at all clear that the first objective is feasible. The issue here is that the data collection scale of the SABAP2 is the pentad (a unit of area which is 9.2 km north to south and 8.2 km east to west). This might well prove to be too coarse to detect the patterns being searched for. In addition, as for the study of human population density in Chapter Six, no socio-economic data exist on a pentad scale. For that chapter, the transformation of the 2011 census data to an estimate of human population size was relatively straightforward; finding an index of socio-economic status per pentad is more challenging.

Methods

Study Area

Greater Gauteng (Fig.1) forms the study area for this chapter. In chapter six, I demonstrated that most of Greater Gauteng which also forms the study area for this thesis, is thinly populated and in reality, mostly rural, so that an estimated 93% of the c. 14 million people within it live in the top quartile of pentads. Thus, I restricted the study area to the 144 pentads with human populations greater than the upper quartile of 12,488 people (Chapter Six). This provides an objective rule to eliminate rural areas. With this restriction, the bird distribution data for this chapter, was the same as that for the previous chapter.

Data and Analysis

Human Population Data

A large variety of socio–economic variables was available within the database of the records of the 2011 South African Census (Statistics South Africa 2015) obtained from the DataFirst Data Portal, University of Cape Town (https://www.datafirst.uct.ac.za/). These variables related to topics such as education status, descriptions of dwellings, household size, and many others. Many of these were not readily transformable into a single summary index per pentad. On advice from Dr Kevin Winter at the Department of Environmental & Geographical Science at the University of Cape Town, I chose to estimate the average monthly income per person in the pentad, also using the 2011 census data. The estimate was derived from data processing carried out in the previous chapter (see Data Analysis section in Chapter Six for further details). I estimated the total income for each block from the different sub–places belonging to a particular pentad, and these incomes were added to provide an estimate of the total income of the people in each pentad in 2011; this was divided by the total number of people per pentad to provide an estimate of income per person. As in Chapter Six, the key assumption is that incomes are uniformly distributed within each sub–place.

Analysis

Data analysis followed the same pattern as used in Chapter Six, except that it was restricted to the 144 pentads with human populations above the upper quartile. For each of the 263 species occurring in more than a quarter of the 576 pentads of Greater Gauteng, I produced a scatterplot, with the logarithm of income on the x–axis and reporting rate on the y–axis. Each scatterplot has 144 points, one for each pentad with human populations above the upper quartile. A smoothed line was fitted through these 144 points, using the same algorithm as in Chapter Six. Smoothed line is interpolated, using a spline function, between 20 points, equally spaced in the logarithmically transformed space of income.

These 20 points which anchor each of the smoothed lines were extracted for each species and compiled into a matrix with 263 rows (one for each species) and 20 columns. The matrix was row–centred, i.e., the mean reporting rate for each row was subtracted from the 20 reporting rates for each species. The key property of this matrix is that the row means are all zero. This matrix was subjected to the covariance biplot (Greenacre and Underhill, 1982), with only the first two dimensions, associated with the largest singular values of the row–centred matrix, retained. The biplot is a method of exploratory data analysis; it is the tool of choice for revealing a small number of key patterns between the rows and columns of a data matrix without preconceptions about what those patterns might be. If there was no strong pattern between income and reporting rate, the singular values would not show a strong decreasing pattern. If the ordered singular values decrease rapidly, then the patterns can readily be uncovered by inspection (Greenacre and Underhill, 1982). The amount of information explained by the first (second) dimension is calculated as the square of the largest (second largest) singular value divided by the sums of squares of all the singular values (Greenacre and Underhill, 1982).

Results

Of the 263 species considered in this analysis, the number that occurred in all 144 pentads with human populations above the upper quartile was 19; and 105 species occurred in more than 100 pentads (Table 7.1). The median number of pentads per species was 87, 60% of the 144 pentads. Thus the species occurred widely across the more densely populated area of Greater Gauteng.

The 263 scatterplots were produced, the smoothed curves fitted, and the matrix with 253 rows and 20 columns was assembled and subjected to the covariance biplot. 72.8% of the information in the matrix was explained by the first dimension of the biplot, and a further 16.5% by the second dimension. This indicates that 89.3% of the information in the 253×20 data matrix can be captured by the first two dimensions.

At this point in the data analysis, it is certain that there is an exceptionally strong relationship between reporting rates of the birds and the incomes of the inhabitants of the 144 pentads under consideration, but there is no information on the nature of the relationship. The covariance biplot provides a score for each bird species along each dimension; I sorted these scores and examined the scatterplots for the species with the largest and smallest scores. The scores for the first and second dimension, sorted on the first dimension, are provided in Table 7.1.

On the first dimension, the species with the largest score was Cape Robin–Chat (*Cossypha caffra)* (Fig. 7.1), followed by Karoo Thrush (*Turdus smithi)* (Fig. 7.2) and Cape White–eye (*Zosterops virens)* (Fig.7.3). These three species are characterized by sharp increases in reporting rate with income. The three species with the smallest scores were Blue Waxbill (*Uraeginthus angolensis)* (Fig. 7.4), Rattling Cisticola (*Cisticola chiniana)* (Fig. 7.5) and Scaly–feathered Finch (*Sporopipes squamifrons)* (Fig. 7.6). These three species are characterized by sharp decreases in reporting rate with income. The species in the central place in the sort of the first dimension was Woodland Kingfisher (*Halcyon senegalensis)* (Fig. 7.7), characterized by an almost horizontal reporting rate. One quarter of the way between the Cape Robin–Chat and the Woodland

Kingfisher is Southern Masked–weaver (*Ploceus velatus)* (Fig. 7.8) which is a gradual increase in reporting rate with income. The species half way between the Blue Waxbill and the Woodland Kingfisher is Cinnamon–breasted Bunting (*Emberiza tahapisi)* (Fig. 7.9) which shows a gradual decrease in reporting rate with income.

At this point, the interpretation of the first dimension becomes clear (Figs 7.1 to 7.9). It is a continuum which contrasts the overall relationship between bird species and income. At the extremes of the continuum are the bird species which strongly "follow–the–money" and those which strongly "follow–poverty", with a gradual trend in the strength of the relationship in between these extremes, with the bird species that are "indifferent to poverty" in the middle. The dimension explains an impressive 72.8% of the information in the large data matrix.

The second dimension explains 16.5% of the information, less than a quarter of that of the first dimension, and it is more subtle in its interpretation. It represents a contrast between species for which the overall pattern is convex or concave. For example, for the Cape Robin–Chat, the curve is convex (increasing rapidly at smaller incomes and then flattening out at higher incomes) (Fig. 7.1). The convex pattern occurred in most other species with reporting rates that generally increased with income (e.g. Figs 7.2 and 7.3). The concave pattern occurred in many species with reporting rates decreasing with income (Figs 7.4 to 7.6). However, the overall pattern for African Pipit (*Anthus cinnamomeus)*, a species with a reporting rate that decreased with income, was convex (Fig. 7.10).

The most interesting examples of species with concave and convex patterns are those that show peaks and valleys of reporting rate at intermediate income valleys. At the extremes on this scale on the second dimension are species such as Long–tailed Widowbird (*Euplectes progne)* (Fig. 7.11) and Cape Longclaw (*Macronyx capensis)* (Fig. 7.12) with peaks of reporting rates at intermediate income values, and those with valleys at intermediate income values, such as Grey Go–away–bird (*Corythaixoides concolor)* (Fig. 7.13) and Pied Crow (*Corvus albus)* (Fig. 7.14).

Given that the species are arranged along dimension 1 of the biplot in a continuum of response to income (Table 7.1), from those with reporting rates that are strongly increasing to those that are strongly decreasing, it is impossible to split them into groups.

But it is feasible to obtain an overall evaluation of the impact of income on reporting rates by counting the number of species in comparable sections of the number line (Table 7.2).

There were 19 species which displayed strong increases of reporting rate in relation to income, in patterns similar to those of Figs 7.1 to 7.3, and 14 with strong decreases (Figs 7.4 to 7.6) (Table 7.2). However, in the remaining comparable groups, the number of increasing species was smaller than the number of increasing species (19 vs 30, 34 vs 70, and 30 vs 47) (Table 7.2). Excluding the 77 species in the two sections of the number line of Table 7.2 on either side of the origin (i.e. from –0.01 to +0.01), there were 74 species which showed increases in reporting rate with increases in income, and 114 which showed decreases. This pattern suggests that, in broad brush terms, the overall impact of increases in average income per person on the reporting rate of birds is negative.

Discussion

Next level label: Novel approach

Perhaps the most important result of this chapter is that this novel approach detected a pattern at all. It was not self–evident, prior to the analysis, that the five–minute grid cells imposed by the pentad system on which the bird atlas is based would be an appropriately–sized unit of area for undertaking an analysis of this nature. The primary concern was that the pentad was too large an area for the estimated mean income per person within it to be a useful measure of the average socio–economic status of the pentad. A scan of the map for any suburban pentad of Gauteng indicates that multiple suburbs are contained with a pentad, and many of these have very different socio–economic statuses. Thus, the analyses of this chapter can be classified as experimental. The results obtained were unexpectedly strong, and thus open the door to further analysis which can investigate the impact of socio–economic factors on bird species distributions more systematically than was undertaken here.

Urban biodiversity

The conservation of biodiversity in urban areas has become one of the new themes of the 21st century, receiving a lot of interest and assuming top conservation priority (Miller and Hobbs, 2002, Grimm et al., 2008, Strohbach et al., 2009). This shift in focus of conservation efforts is further enhanced by growing knowledge on the serious conservation challenges posed by urbanization which include the greatest local extinction rates of biodiversity as well as the loss, fragmentation and degradation of local habitats, often with irreversible effects (Stein et al., 2000, Marzluff, 2001, McKinney, 2002, Mikkelson et al., 2007). Urbanization is expanding at a rate with an estimated 70% of world's population expected to live in urban areas by the year 2050 (Vitousek et al., 1997, Wu, 2010, United Nations, 2014). This makes it imperative that a special focus is placed on the conservation of biodiversity in urban spaces and monitor how urbanization and other human activities in urban spaces impact biodiversity. Given that urbanization is not just described through physical processes, it has been argued that urban biodiversity should be considered in the context of socioeconomic patterns as described by household income among others (Alberti et al., 2003, Strohbach et al., 2009).

This chapter opens up a new quantitative approach to the study of urban biodiversity. In it, I discuss patterns of relationship between a socioeconomic factor (i.e. *per capita* income) and bird species abundance measured by reporting rates of birds in the 144 pentads of Greater Gauteng which had human populations more than the upper quartile. The results obtained in this chapter showed that for many species, there was on the pentad scale, a correlation between mean income levels of residents and the patterns of abundance of many bird species in Greater Gauteng (Table 7.2). This relationship is a continuum (Table 7.1), so it is not feasible to classify species simply as “wealth lovers” or “wealth avoiders”. But a remarkable aspect of Table 7.2 is the fact that relatively few species were in the two central classes, which show insensitivity between reporting rates and mean income.

The 19 species in the first category of Table 7.2, listed in Table 7.1, are all clearly “wealth lovers”. They show no conspicuous common factors. They belong to 16 families; they include multiple diet categories; they vary widely in size; there are both waterbirds and terrestrial species. What these species must have in common is the ability to benefit from some of the kinds of habitat modification undertaken by wealthy humans, such as the creation of manicured gardens with lawns, shrubs and trees, and the creation of recreational parks and other green spaces with artificial wetlands, often with reedbeds, mown lawns, and patches of woodland habitat with a dense understory of scrub, weeds, rank grass, restios and ferns. These habitats types are characteristic of wealthy neighborhoods where home gardens, parks and other human–altered and modified landscapes and green spaces are common features (McKinney, 2002, Grimm et al., 2008, Loss et al., 2009, Taylor et al., 2015).

At the other end of the scale are the 14 “wealth avoiders” in the last category of Table 7.2, listed in Table 7.1. They are all passerines and are mostly small. Two of the 14 species are granivores (Scaly–feathered Finch and Blue Waxbill), and the remaining 12 are insectivores.

The second dimension of the biplot focused on a contrast between species with a concave pattern and species with a convex pattern (Figs 7.1–7.14). This pattern would not be changed by the use of a logarithmic scale for the income (horizontal) axis; however, it might be an artefact of the use of the reporting rate scale as a proxy to measure abundance (vertical axis). This is however unlikely because theoretical considerations suggest that abundance is proportional to –log (1 – reporting rate) (Underhill & Brooks 2016). This relationship is approximately linear for reporting rates less than about 80%. The intriguing insight provided by the second dimension was that species with reporting rates which increased with income were convex in shape (Figs 7.1–7.3), and that species with reporting which decreased were mostly concave (Figs 7.4–7.6, with Fig. 7.10 as a contrast). Understanding this pattern is a topic for further investigation.

The most puzzling species were those which showed no overall trend in reporting rate (i.e. close to zero on dimension 1) but were either strongly convex (e.g. Figs 7.11 and 7.12) or concave (Figs 7.13 and 7.14). These patterns could potentially be an artefact involving other explanatory variables but do appear to be well supported by the scatterplots. As with the first dimension, there is a continuum of patterns, but the number of species with patterns as extreme as those demonstrated in Figs 7.11–7.14 is small. Investigating these patterns is likely to be a rewarding research project.

This chapter asked the question whether the bird atlas data, with the spatial limitation of the five–minute pentad scale, would even be able to demonstrate a relationship between bird reporting rates and the fundamental socioeconomic metric, mean income level. The results confirm that this can be achieved. The chapter has described patterns, but it is beyond its scope to explain them. Previous studies, based on data collected by a variety of protocols, have reported a positive relationship between socioeconomic status and avian species richness in urban contexts (Hope et al., 2003, Kinzig et al., 2005, Melles, 2005, Strohbach et al., 2009). The emerging consensus from these studies is that species richness is larger in wealthier suburbs than in poorer suburbs and was explained as a consequence of the structural differences in vegetation between high and low–income areas. High–income areas tend to have better quality green spaces than low–income areas (Heynen, 2003, Pauleit et al., 2005, Tratalos et al., 2007, MacGregor–Fors, 2008). The results from this study in Greater Gauteng does not, however, support these findings. Table 7.2 suggest that more species have a negative relationship between abundance and *per capita* income than species which showed a positive relationship. This needs further evaluation and research.

CONCLUSIONS

Overall, mechanistic explanations of the diverse results reported in this chapter provides a rich field of study for future research. A possible explanation may be related to the location of Greater Gauteng in Africa; the earlier studies in this field were undertaken in temperate regions. The implication is that areas which, at face value, may be categorized as low–income and environmentally disadvantaged in the tropics contain qualitatively different habitats from the adjacent wealthy areas, and therefore attract a different community of bird species. In comparison, environmentally disadvantaged areas in cities in the temperate region seem to have impoverished bird communities compared to the wealthy areas. The working hypotheses are therefore (1) that the bird communities in disadvantaged sections of tropical cities are different from those of the wealthy sections, and (2) that the bird species richness of the disadvantaged sections of tropical cities is greater than the equivalent sections of temperate region cities.

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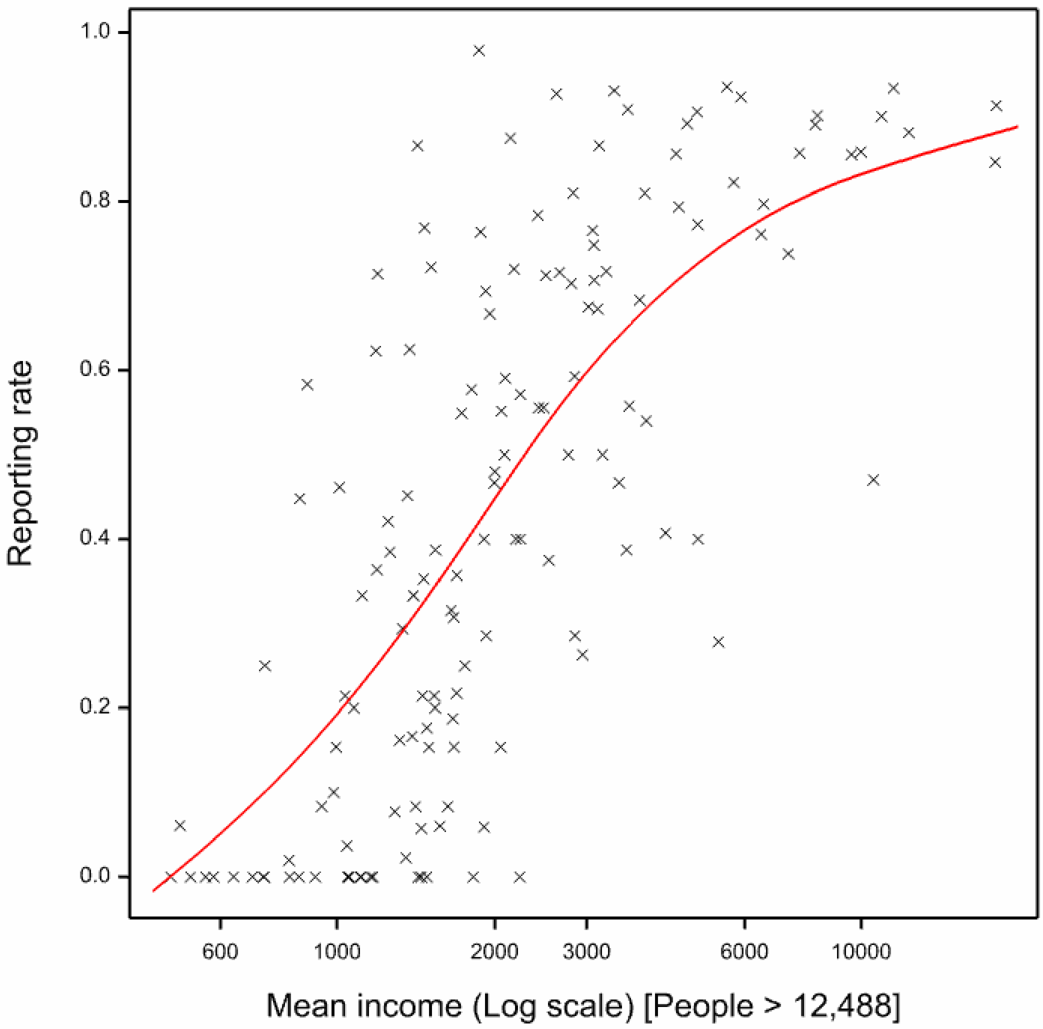

Fig. 7.1: Relationship between reporting rate of the Cape Robin–Chat and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

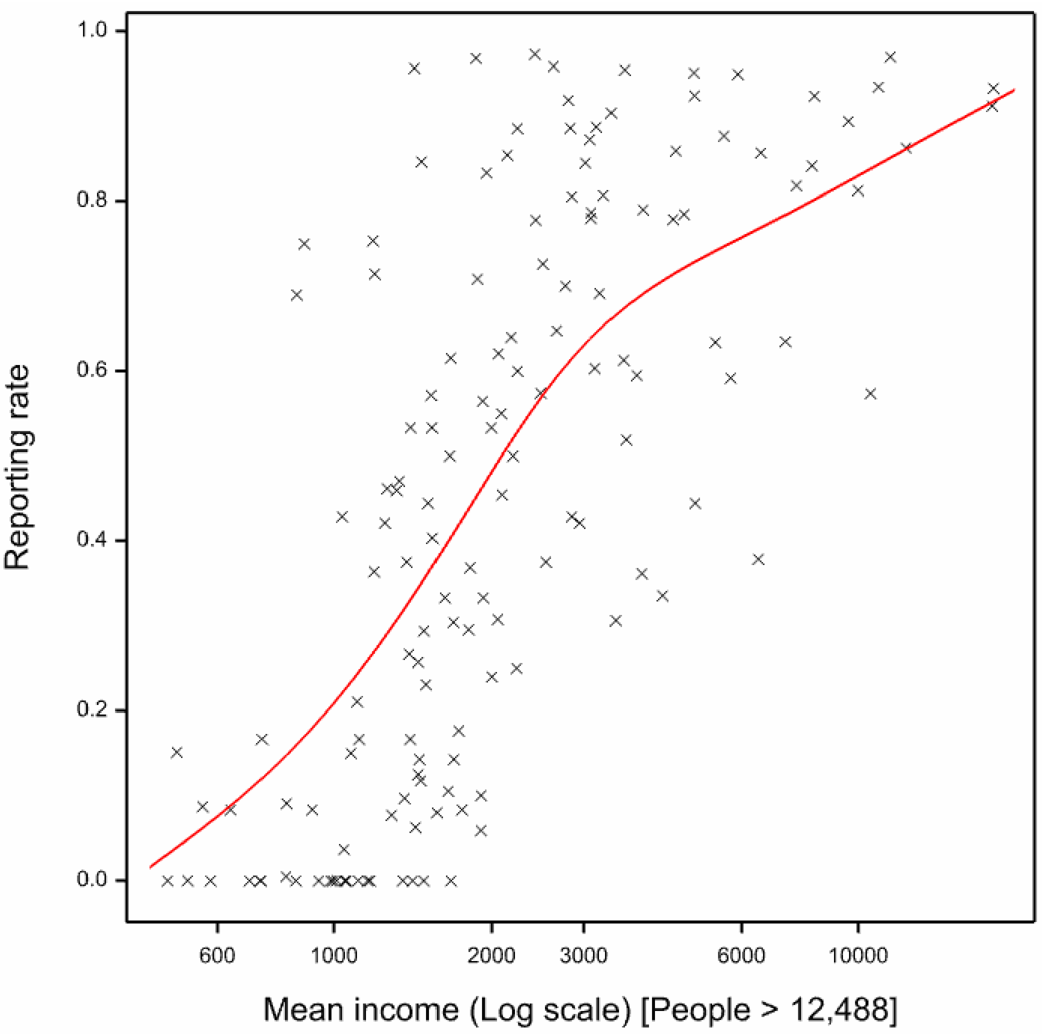

Fig. 7.2: Relationship between reporting rate of the Karoo Thrush and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

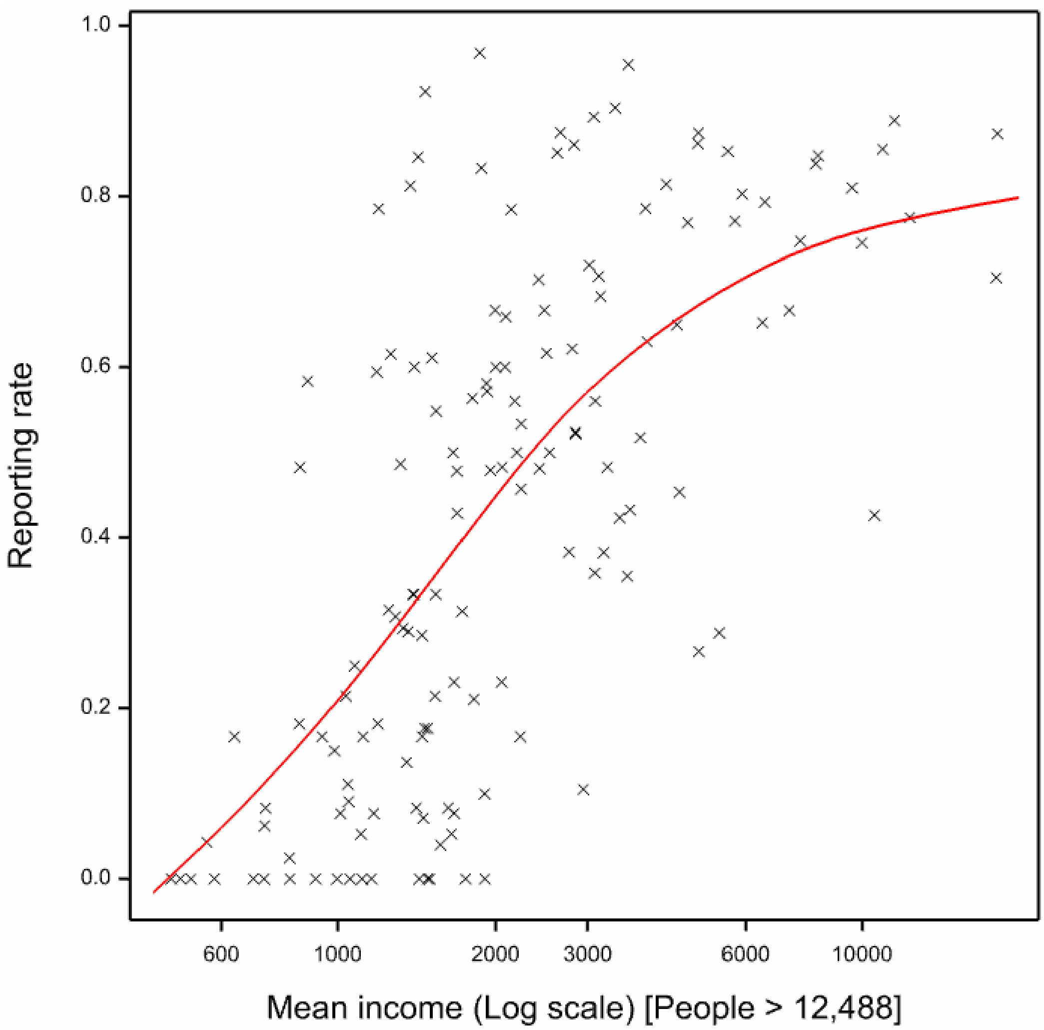

Fig. 7.3: Relationship between reporting rate of the Cape White–eye and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

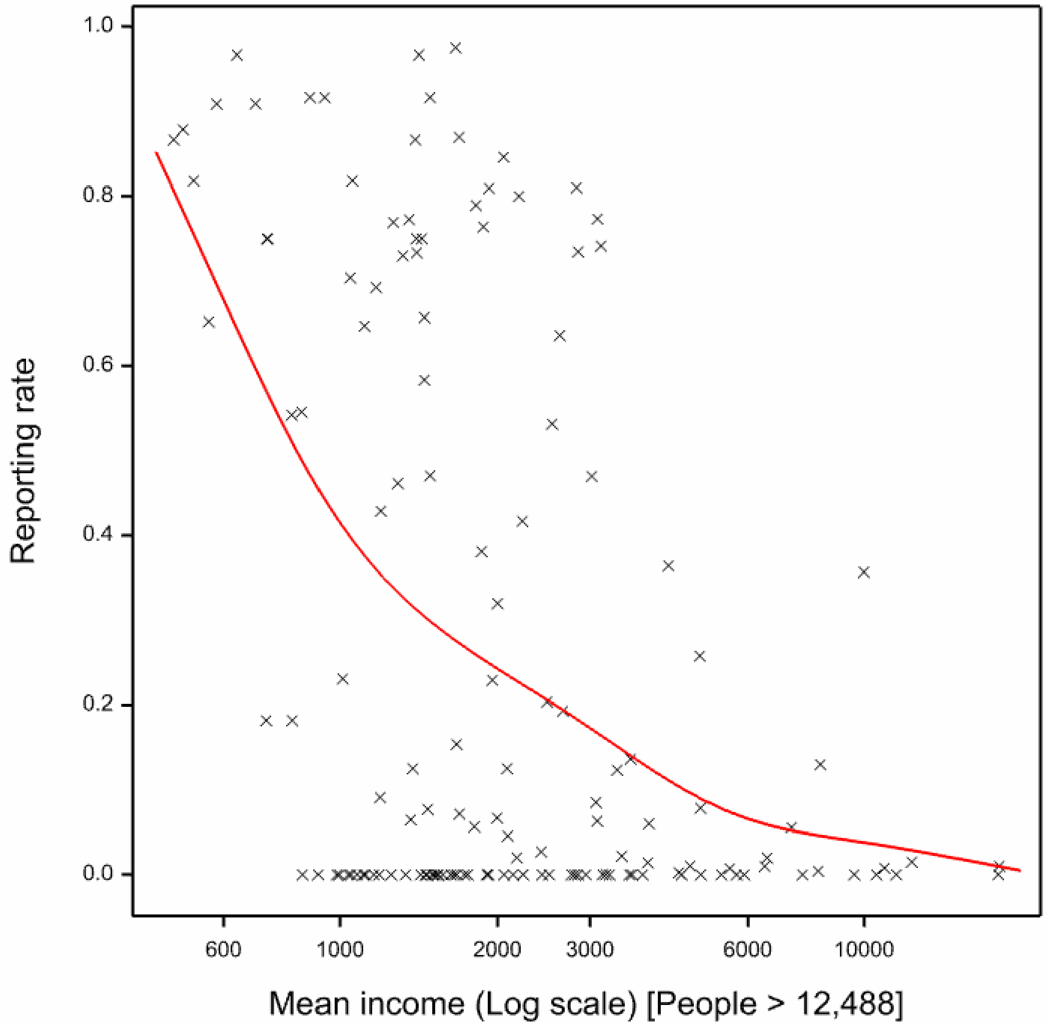

Fig. 7.4: Relationship between reporting rate of the Blue Waxbill and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

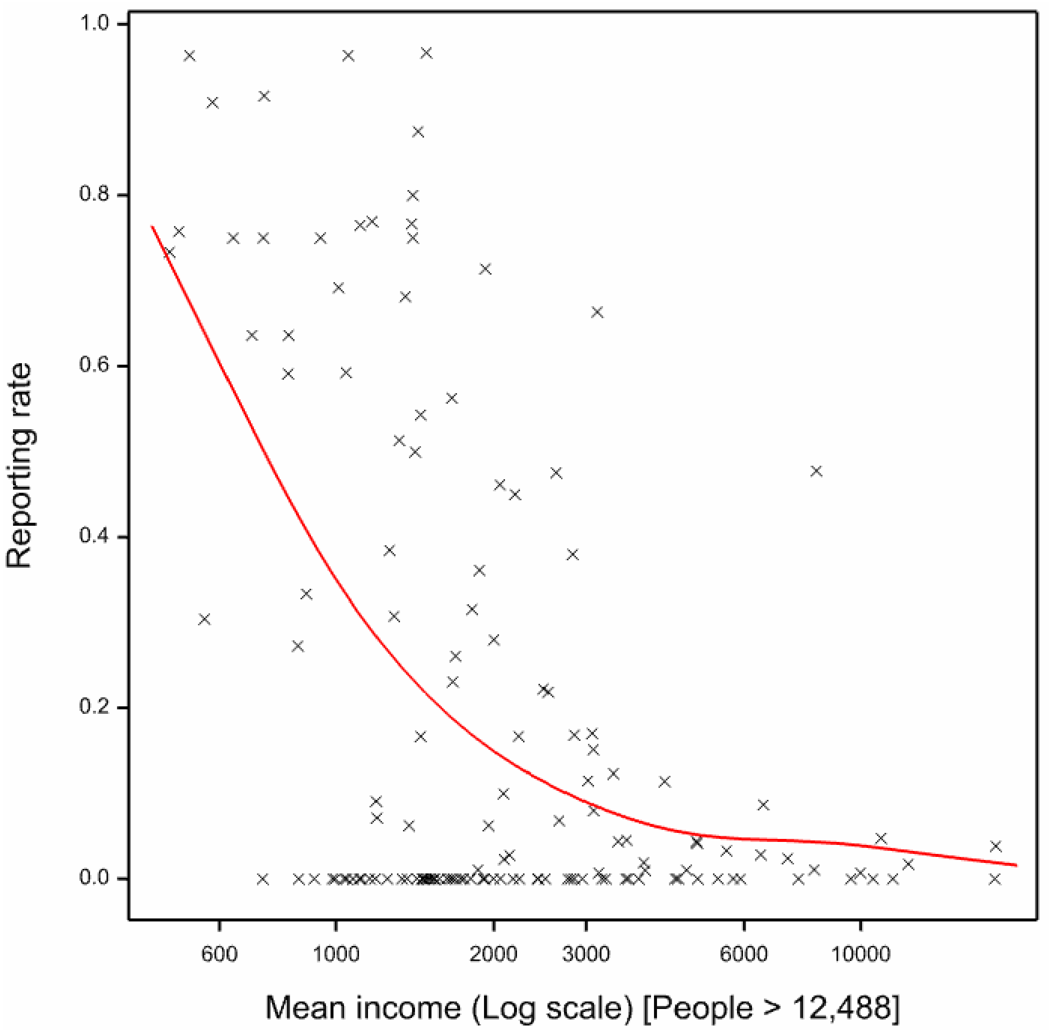

Fig. 7.5: Relationship between reporting rate of the Rattling Cisticola and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

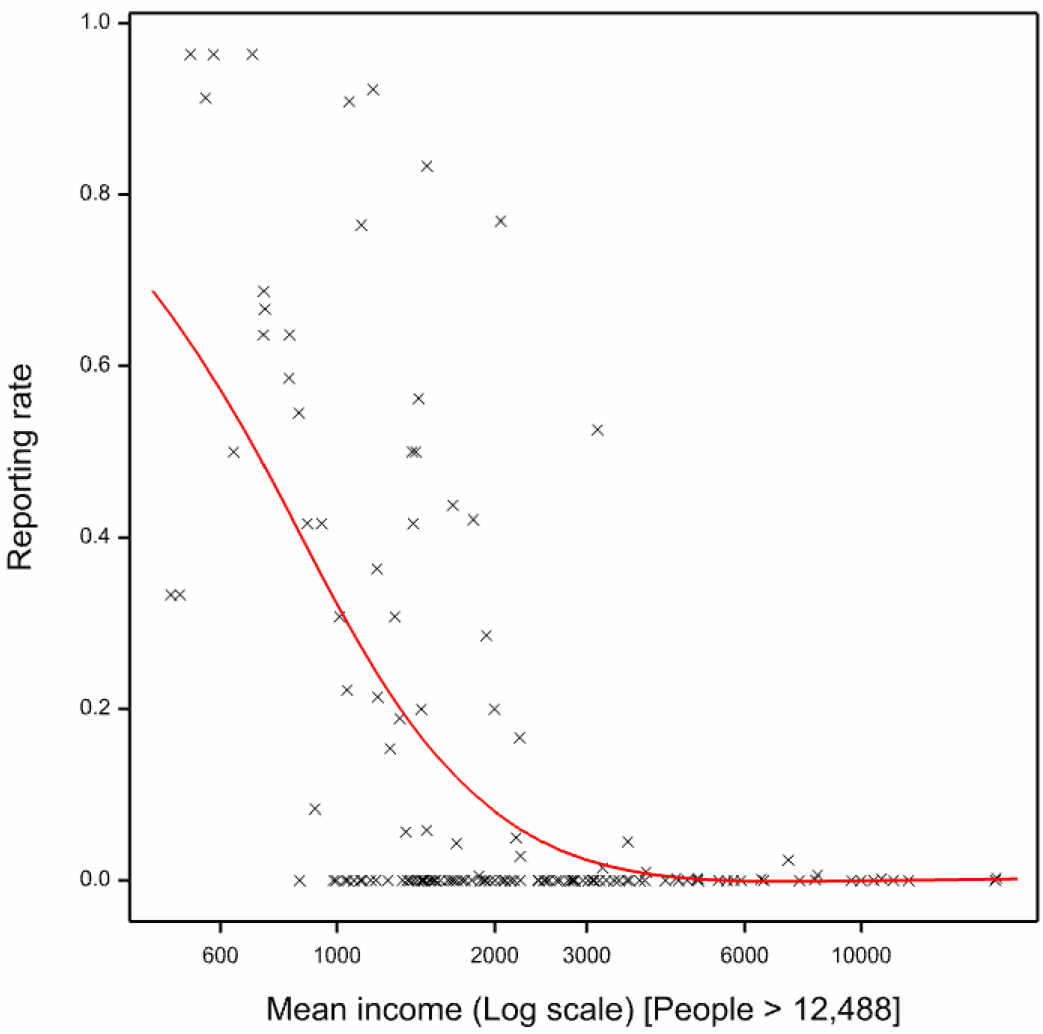

Fig. 7.6: Relationship between reporting rate of the Scaly–feathered Finch and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

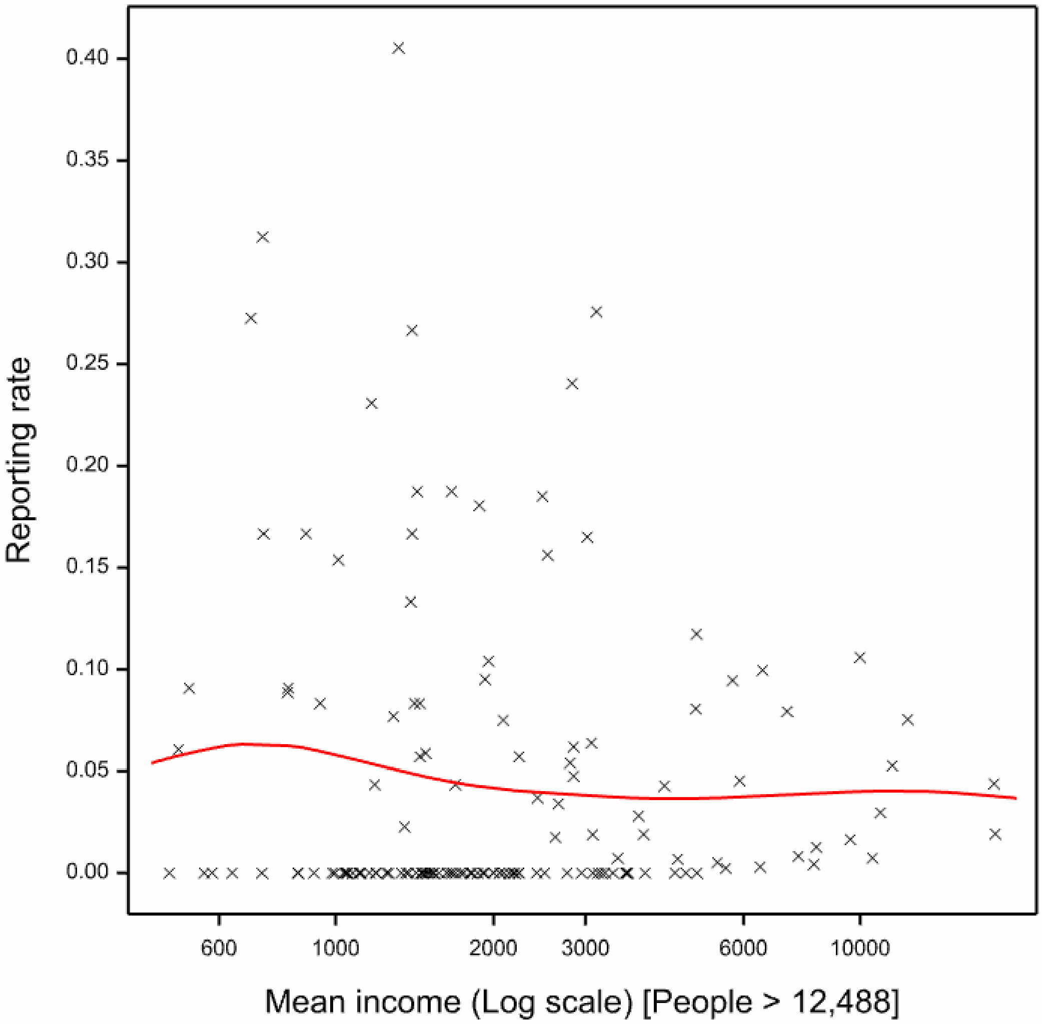

Fig. 7.7: Relationship between reporting rate of the Woodland Kingfisher and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

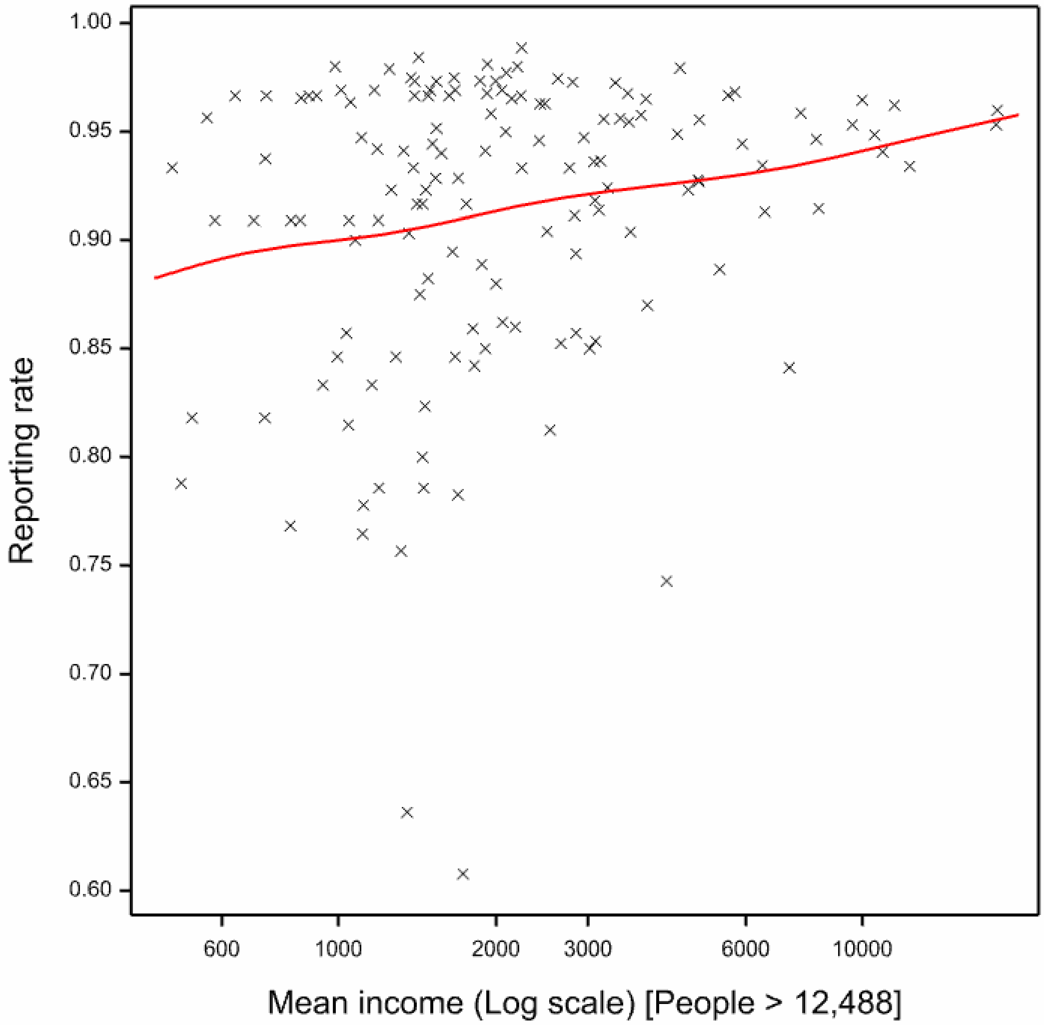

Fig. 7.8: Relationship between reporting rate of the Southern Masked–weaver and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

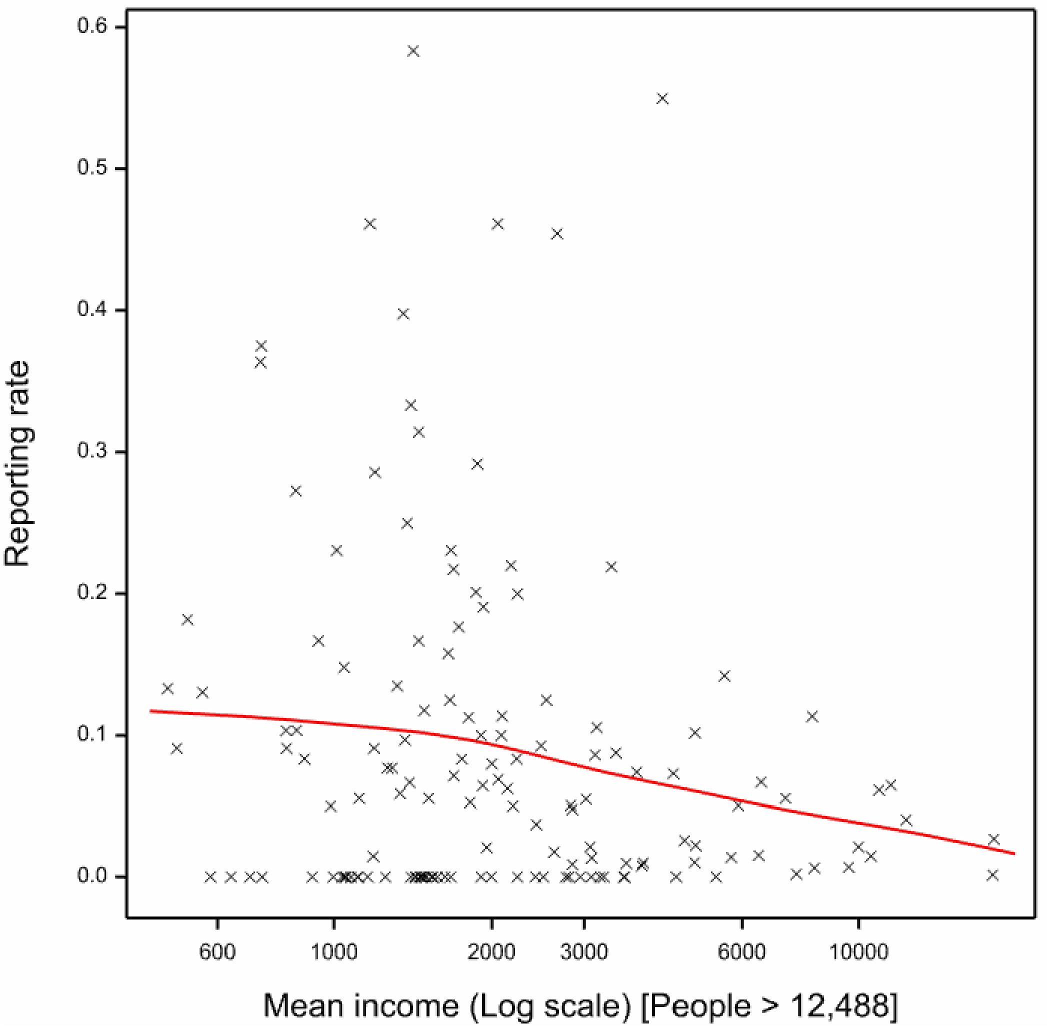

Fig. 7.9: Relationship between reporting rate of the Cinnamon–breasted Bunting and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

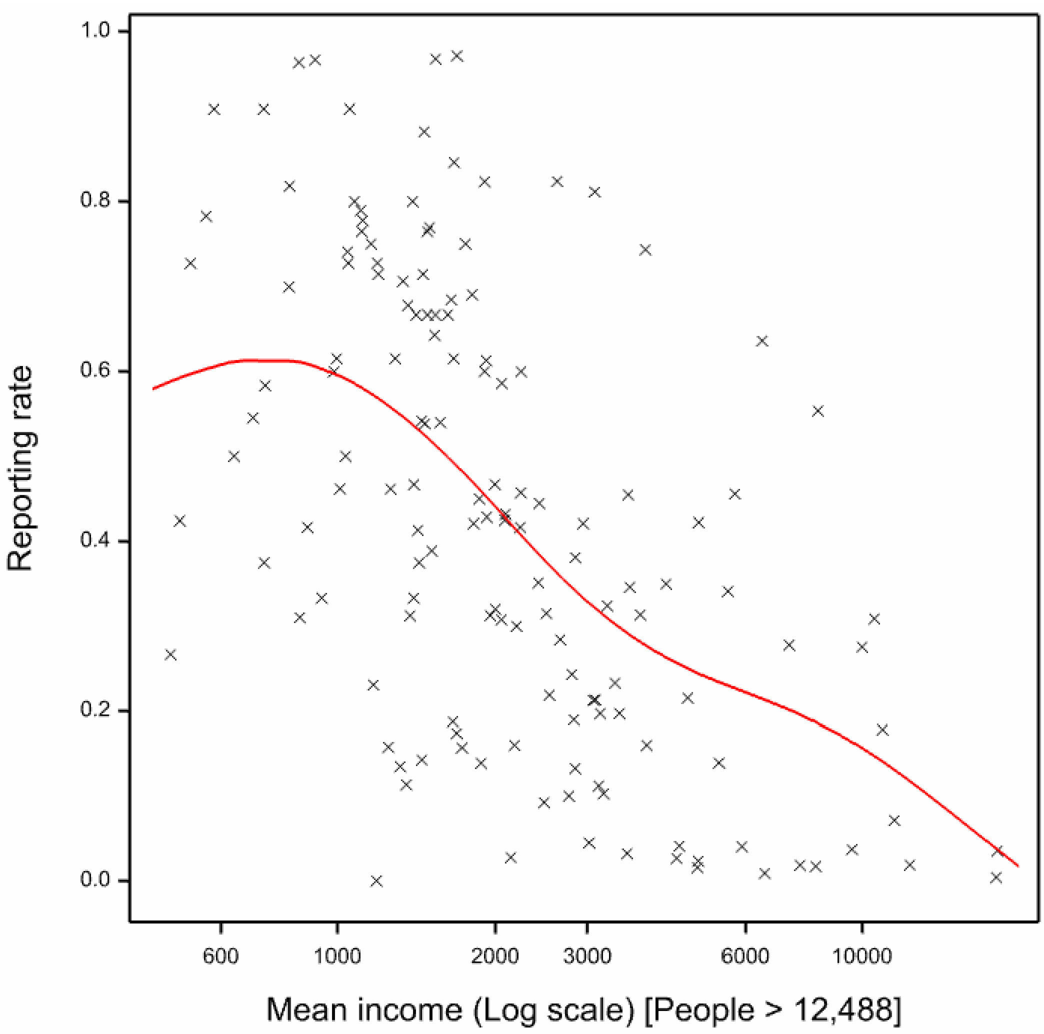

Fig. 7.10: Relationship between reporting rate of the African Pipit and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

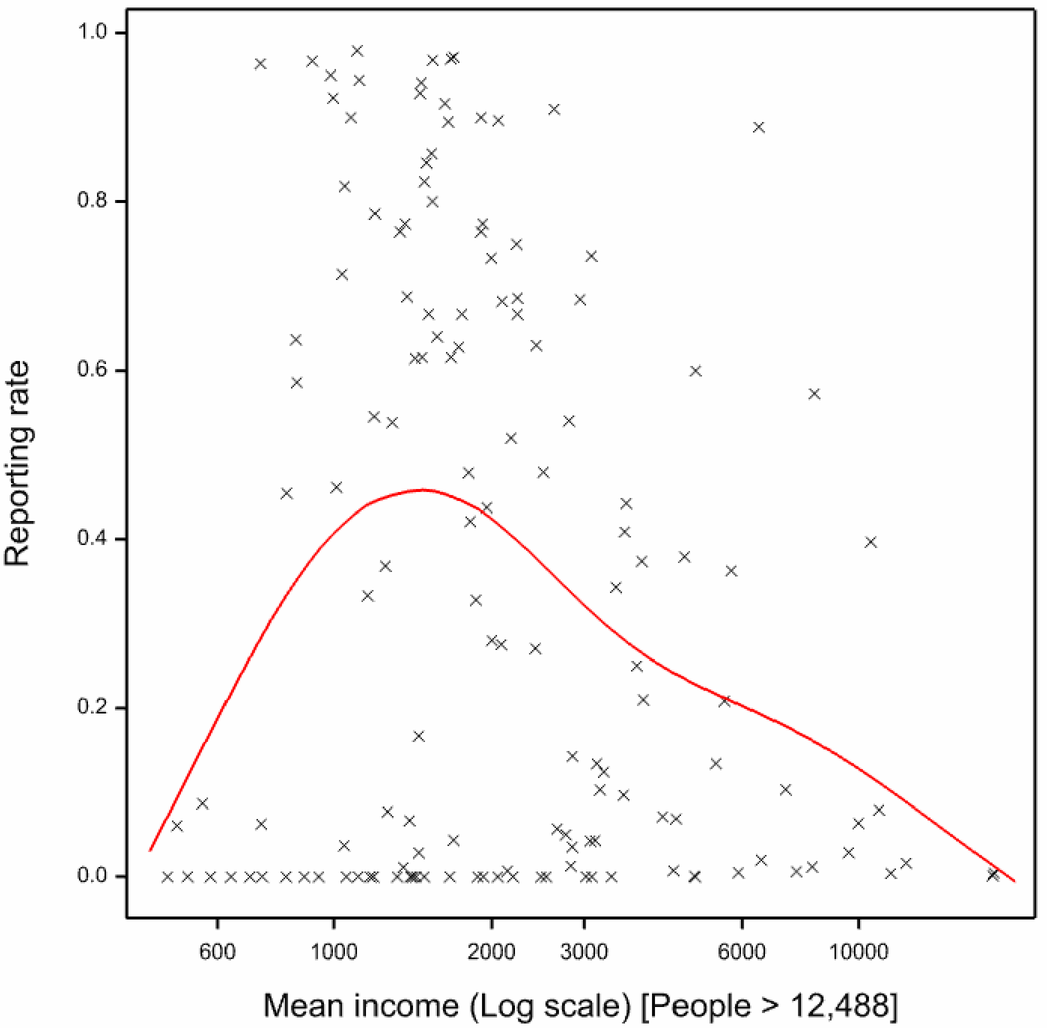

Fig. 7.11: Relationship between reporting rate of the Long–tailed Widowbird and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

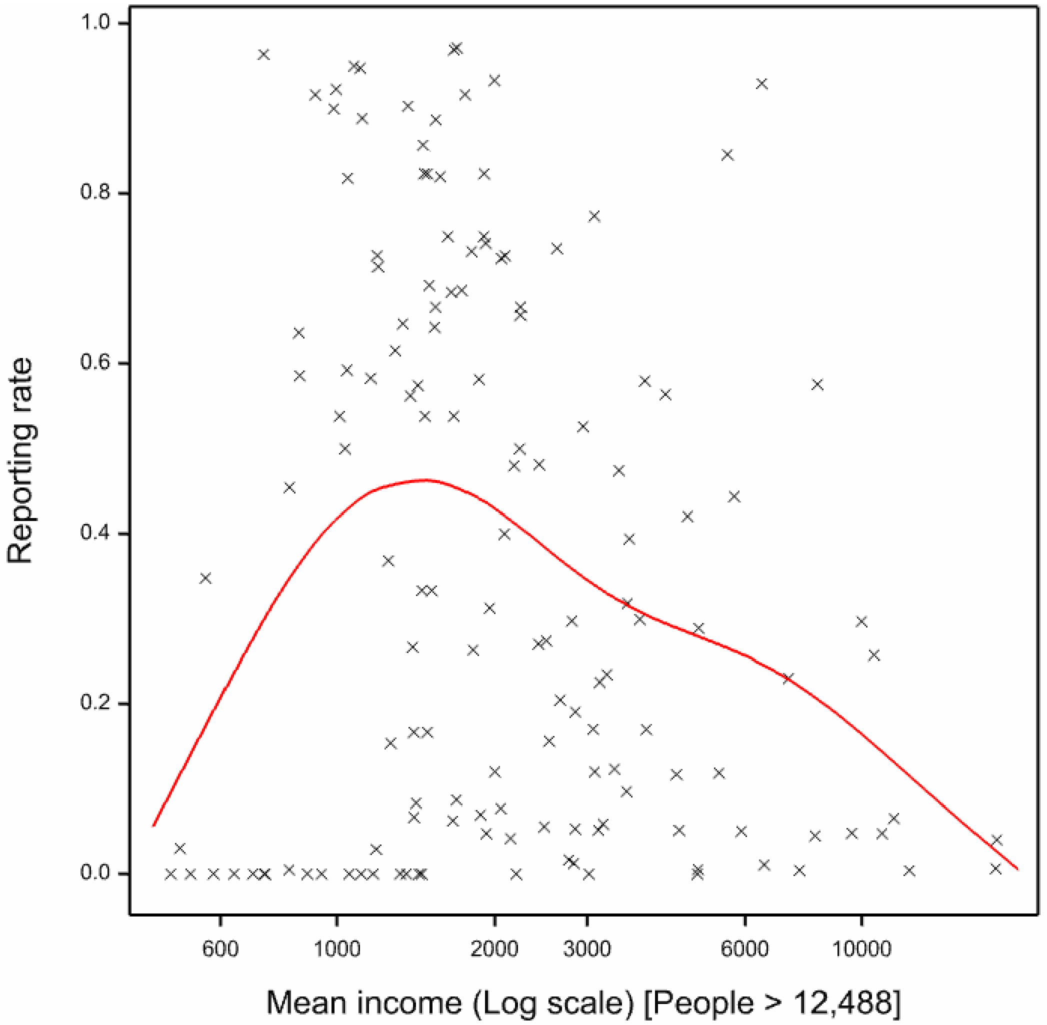

Fig. 7.12: Relationship between reporting rate of the Cape Longclaw and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

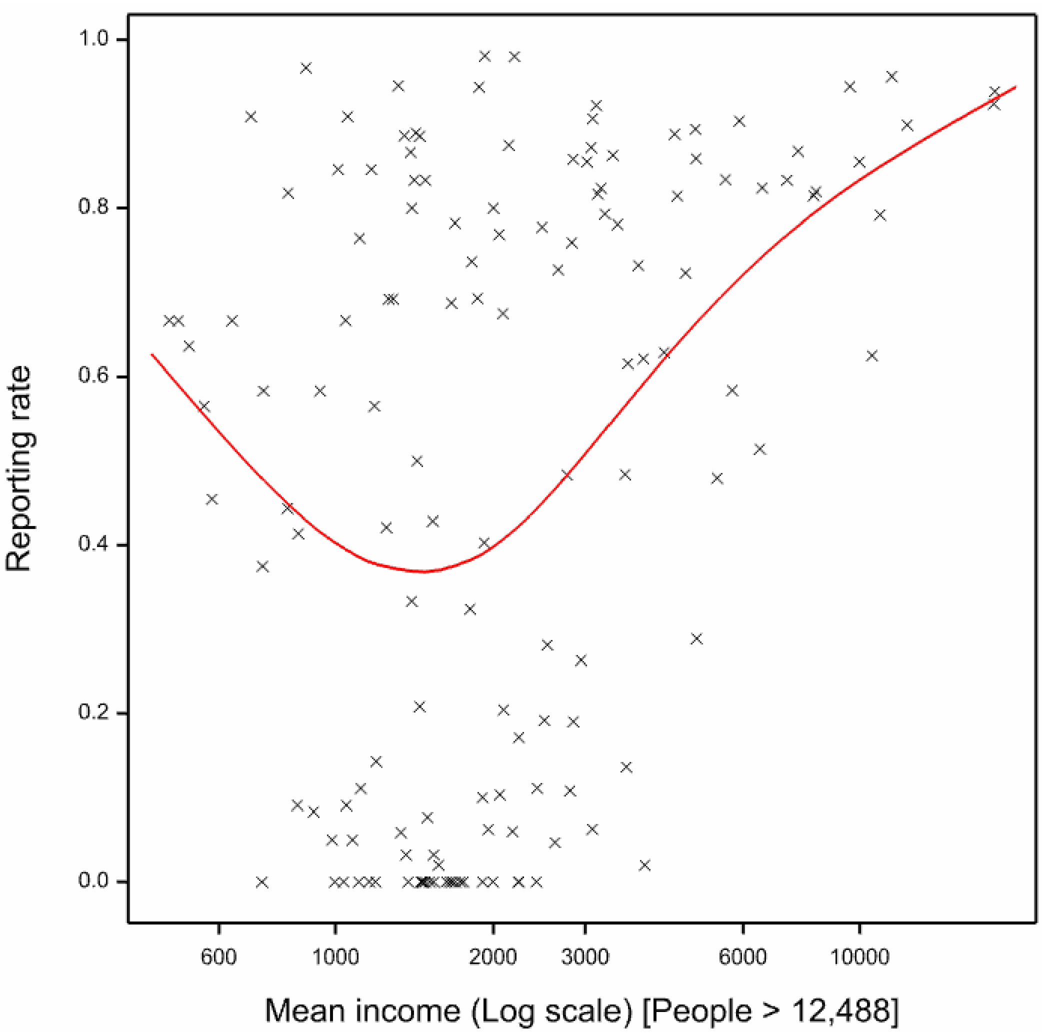

Fig. 7.13: Relationship between reporting rate of the Grey Go–away–bird and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

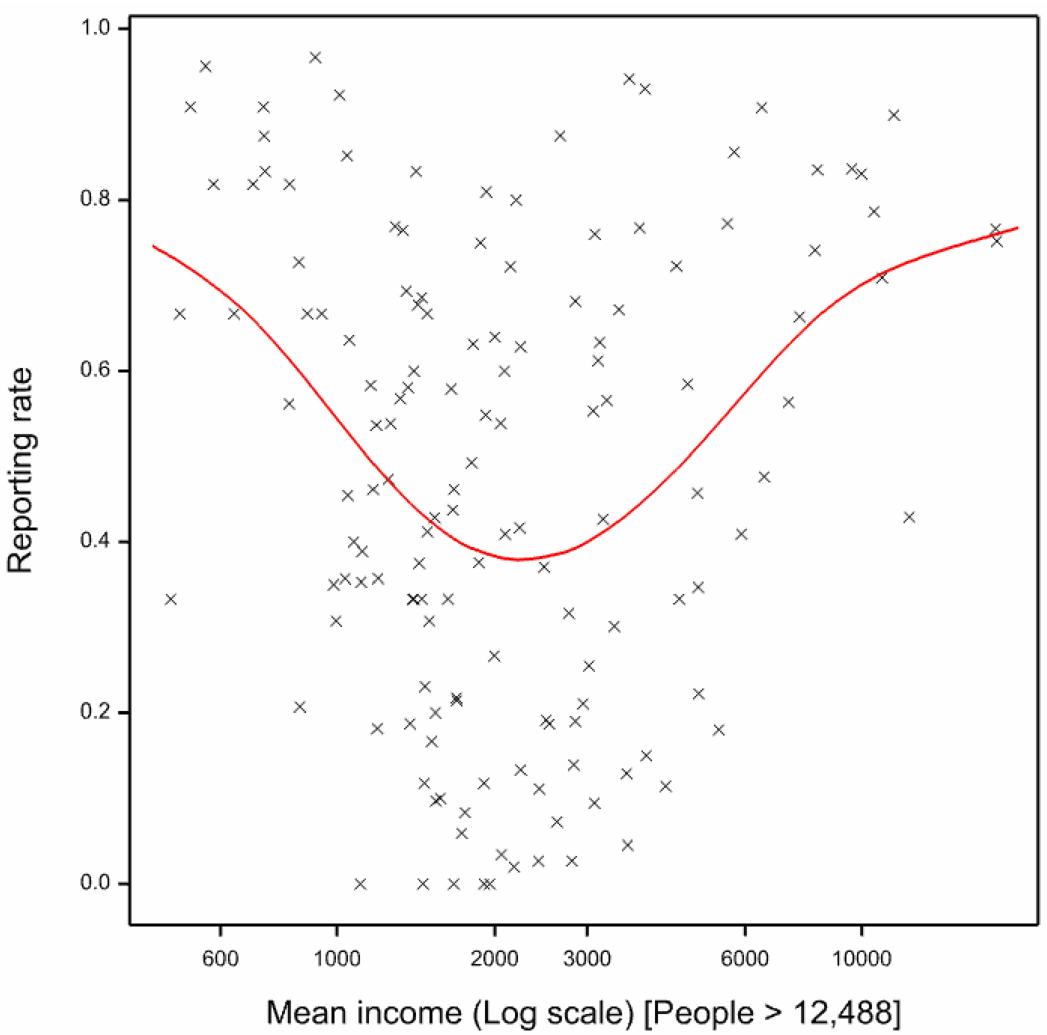

Fig. 7.14: Relationship between reporting rate of the Pied Crow and log of mean income of the human population in Greater Gauteng from pentads with people greater than 12,488.

Table 7.1 The results of the covariance biplot are given in Dimensions 1 and 2. These are the coordinates for plotting the point for each species in two dimensions. The species are sorted on Dimension 1, the species at the top of the table are the “wealth followers” and the species at the bottom of the table are the health avoiders (see text for further details). Also provided is the number of pentads in which each species was recorded; the pentads were restricted to those with human populations above the upper quartile of the population of Greater Gauteng, 12,488 people.

Common Species Name	Species occurrence range (No. of pentads)	Dimension 1	Dimension 2
Cape Robin–Chat	122	–0.24031	–0.01481
Karoo Thrush	124	–0.237	–0.0205
Cape White–eye	127	–0.21227	0.01089
Egyptian Goose	140	–0.17065	0.01593
Crested Barbet	139	–0.15766	–0.05875
Spotted Thick–knee	125	–0.15175	–0.07525
Hadeda Ibis	143	–0.14894	0.07348
Thick–billed Weaver	104	–0.1444	–0.06319
African Sacred Ibis	136	–0.13242	0.01738
Black–collared Barbet	137	–0.13081	–0.0819
Red–eyed Dove	144	–0.12262	0.04257
African Black Duck	104	–0.11465	–0.09511
Common Fiscal	143	–0.11075	0.14384
Green Wood–Hoopoe	125	–0.1106	–0.08188
African Wattled Lapwing	134	–0.11008	–0.08674
Grey Go–away–bird	119	–0.10775	–0.22792
Speckled Mousebird	141	–0.10646	–0.10204
Fiscal Flycatcher	130	–0.10322	0.00579
African Hoopoe	133	–0.10087	0.00367
Helmeted Guineafowl	141	–0.09794	0.04511
Tawny–flanked Prinia	136	–0.09738	–0.11308
Common Moorhen	133	–0.09217	–0.08268
Rock Martin	106	–0.09	–0.09386
Dark–capped Bulbul	141	–0.08609	–0.09184
Rock Dove	144	–0.07358	–0.06073

Cape Sparrow	144	–0.07266	0.00901
Amethyst Sunbird	116	–0.07099	–0.07988
African Darter	118	–0.06488	0.02443
Red–knobbed Coot	139	–0.06432	0.06635
Cape Turtle–Dove	144	–0.06295	0.03267
Streaky–headed Seedeater	105	–0.06159	0.04219
African Palm–Swift	143	–0.06104	–0.05187
Southern Red Bishop	143	–0.06017	0.06991
Cape Glossy Starling	143	–0.05989	–0.13708
Cape Wagtail	141	–0.05826	0.1166
Yellow–billed Duck	138	–0.0574	0.07742
Red–winged Starling	95	–0.05282	–0.02837
African Paradise–Flycatcher	95	–0.05115	0.00137
White–rumped Swift	143	–0.04982	0.00959
Red–headed Finch	121	–0.04856	0.02171
Grey–headed Gull	89	–0.04827	0.08031
Southern Boubou	97	–0.04747	–0.14635
Red–faced Mousebird	144	–0.04392	–0.05564
Bar–throated Apalis	87	–0.04285	0.00137
Lesser Honeyguide	90	–0.04207	–0.04858
Ovambo Sparrowhawk	54	–0.04126	–0.04488
African Stonechat	135	–0.03846	0.22062
Common Myna	144	–0.03844	–0.00435
Willow Warbler	112	–0.03543	–0.02471
Reed Cormorant	143	–0.03533	0.02071
Spotted Eagle–Owl	58	–0.03466	–0.03592
Greater Striped Swallow	143	–0.03317	0.02474
Black–headed Heron	143	–0.03291	–0.01369
Red–throated Wryneck	97	–0.03271	0.02383
White–throated Swallow	139	–0.03194	–0.01508
Bronze Mannikin	93	–0.03191	–0.05689
Black–backed Puffback	76	–0.03099	–0.03788

Crowned Lapwing	144	–0.03069	0.04042
African Reed–Warbler	106	–0.02886	–0.00279
Bokmakierie	108	–0.02764	0.08508
Blacksmith Lapwing	144	–0.02514	0.04297
White–breasted Cormorant	115	–0.02422	0.04244
Green–backed Heron	73	–0.02368	–0.03368
Lesser Swamp–Warbler	129	–0.02168	0.0827
Kurrichane Thrush	81	–0.02133	0.03889
White–bellied Sunbird	124	–0.01909	–0.07715
Southern Masked–Weaver	144	–0.01622	–0.00518
Red–chested Cuckoo	108	–0.01582	–0.03043
Cape Weaver	84	–0.01431	0.00272
Greater Honeyguide	74	–0.01372	–0.01664
Grey–headed Bush–Shrike	43	–0.01156	0.00393
Giant Kingfisher	85	–0.01045	–0.00261
Cape Grassbird	51	–0.00989	0.0068
Malachite Kingfisher	92	–0.00981	–0.0146
Pied Crow	139	–0.00957	–0.21137
Little Swift	142	–0.00955	–0.01388
Red–collared Widowbird	118	–0.0094	0.07261
Grey Heron	133	–0.00819	0.00214
Common Ostrich	60	–0.00769	0.03308
Greater Flamingo	43	–0.00738	0.03188
Mountain Wheatear	86	–0.00716	0.0464
Fairy Flycatcher	55	–0.00658	0.00173
Black Cuckooshrike	37	–0.00652	0.00151
Marsh Warbler	64	–0.00532	–0.01396
Barn Owl	61	–0.00502	0.00434
White Stork	57	–0.00499	0.00859
Laughing Dove	144	–0.00454	–0.00997
Cape Shoveler	72	–0.00447	0.0544
Black–headed Oriole	80	–0.00426	–0.00189

Golden–tailed Woodpecker	67	–0.00416	–0.00554
Cardinal Woodpecker	98	–0.00402	–0.03724
Wailing Cisticola	54	–0.00337	0.0271
Lazy Cisticola	44	–0.00263	0.01155
Horus Swift	52	–0.00249	0.00187
Little Rush–Warbler	110	–0.00227	–0.00757
African Black Swift	64	–0.0021	0.00643
Marsh Owl	71	–0.00176	0.01629
Southern Pochard	86	–0.00165	0.04367
Great Crested Grebe	54	–0.0016	0.03136
Fulvous Duck	57	–0.00115	0.01737
Secretarybird	28	–0.00002	0.00645
South African Shelduck	54	–0.00002	0.02363
Swainson's Spurfowl	142	0.00023	0.05202
Comb Duck	30	0.00034	0.0023
Levaillant's Cisticola	135	0.00138	0.16273
Great Reed–Warbler	66	0.00186	–0.00368
Black Heron	63	0.00198	0.00675
African Purple Swamphen	95	0.00248	0.04824
Black–crowned Night–Heron	79	0.00259	0.00721
Black Cuckoo	53	0.00266	–0.0106
Rock Kestrel	47	0.00318	0.00998
African Fish–Eagle	55	0.0032	0.01284
Familiar Chat	82	0.00322	0.03907
European Bee–eater	119	0.00331	–0.08938
Common House–Martin	75	0.00344	–0.01774
African Grey Hornbill	81	0.00346	–0.0294
Plain–backed Pipit	48	0.00352	0.00741
Common Swift	52	0.00384	–0.01118
Squacco Heron	90	0.00391	0.03553
Common Quail	34	0.00403	0.00435
Lesser Kestrel	41	0.00433	0.00288

Village Weaver	75	0.0044	0.00609
Levaillant's Cuckoo	40	0.00536	–0.00766
Yellow–billed Kite	72	0.00559	–0.02807
Whiskered Tern	79	0.0057	0.0416
Lanner Falcon	48	0.00615	–0.00622
Buffy Pipit	47	0.00616	0.00776
Yellow–fronted Tinkerbird	57	0.00617	0.01748
Orange River Francolin	67	0.00626	0.06122
Long–billed Pipit	52	0.0065	0.00909
Woodland Kingfisher	68	0.00665	–0.00387
Black–faced Waxbill	26	0.00667	0.0041
Marsh Sandpiper	41	0.00712	0.01197
Goliath Heron	66	0.00716	0.00815
Yellow–throated Petronia	32	0.00734	–0.0055
Violet–backed Starling	41	0.0076	0.00266
White–winged Tern	48	0.00783	0.01953
African Red–eyed Bulbul	48	0.00788	0.09217
Brown Snake–Eagle	29	0.00807	–0.00942
Wing–snapping Cisticola	72	0.00829	0.03464
Southern Black Tit	31	0.0083	0.00285
White–backed Duck	47	0.00841	0.00575
Pied Starling	91	0.00852	0.10931
Banded Martin	67	0.00946	0.01547
Southern Black Flycatcher	47	0.00953	0.00899
South African Cliff–Swallow	95	0.00962	0.06112
Yellow–billed Egret	75	0.00962	0.01459
Purple Heron	116	0.00965	0.02296
Orange–breasted Bush–Shrike	42	0.00984	–0.00647
Black–crowned Tchagra	68	0.01055	0.01521
Jameson's Firefinch	68	0.0107	–0.02716
Steppe Buzzard	113	0.01088	–0.0133

Groundscraper Thrush	80	0.01141	0.02368
Kittlitz's Plover	28	0.01167	0.00826
Jacobin Cuckoo	39	0.01178	–0.01332
Little Bee–eater	39	0.01179	–0.01107
Eastern Clapper Lark	57	0.012	0.04312
Glossy Ibis	124	0.01219	0.11567
Gabar Goshawk	52	0.0122	–0.01052
Orange–breasted Waxbill	90	0.01229	0.01277
Common Greenshank	63	0.01276	0.01524
Little Stint	50	0.01287	0.02278
African Spoonbill	92	0.01295	0.03483
Little Egret	123	0.01331	–0.00179
Coqui Francolin	56	0.01389	0.00995
Village Indigobird	36	0.01406	–0.01256
House Sparrow	144	0.01466	–0.00223
Klaas's Cuckoo	52	0.01521	–0.01705
Pied Kingfisher	115	0.01552	0.012
Yellow–fronted Canary	80	0.01603	–0.05167
Common Sandpiper	68	0.01621	–0.01135
Anteating Chat	71	0.01648	0.08262
Spike–heeled Lark	58	0.01717	0.04889
Ruff	57	0.01731	0.02236
White–backed Mousebird	54	0.01753	0.00969
Amur Falcon	117	0.01831	0.05174
African Jacana	56	0.01834	–0.00717
Pied Avocet	52	0.01969	–0.00673
Great Egret	69	0.01983	–0.00082
Brubru	55	0.02121	0.0123
Violet–eared Waxbill	38	0.02182	–0.02056
Shaft–tailed Whydah	30	0.02204	–0.0219
Spotted Flycatcher	126	0.02222	–0.00005
Cloud Cisticola	91	0.02233	0.10592

Speckled Pigeon	144	0.0228	0.03022
Red–capped Lark	73	0.0231	0.0593
Brown–throated Martin	134	0.02348	0.08843
Greater Kestrel	58	0.02474	–0.0254
Wattled Starling	108	0.02476	0.06994
Cinnamon–breasted Bunting	101	0.02504	0.01526
Grey–backed Camaroptera	46	0.02557	–0.03366
Chestnut–backed Sparrowlark	19	0.0256	–0.03413
Hamerkop Hamerkop	109	0.02615	–0.0068
Black Crake	98	0.0264	–0.00242
Red–billed Firefinch	59	0.02747	–0.02826
Capped Wheatear	94	0.02762	0.08173
Black–chested Snake–Eagle	63	0.02907	–0.03338
Pearl–spotted Owlet	35	0.02909	–0.03856
Arrow–marked Babbler	79	0.02958	–0.00446
African Snipe	98	0.02962	0.03894
Spur–winged Goose	118	0.03163	0.05986
Burnt–necked Eremomela	35	0.03298	–0.03524
Long–tailed Paradise–Whydah	58	0.0344	–0.03538
Natal Spurfowl	60	0.03447	–0.0327
Brown–hooded Kingfisher	92	0.03504	–0.06604
Golden–breasted Bunting	56	0.03731	–0.01215
White–throated Robin–Chat	56	0.03734	–0.01789
Cattle Egret	144	0.03736	0.01274
Wood Sandpiper	91	0.03857	0.00525
Cape Longclaw	125	0.03868	0.24418
Cape Teal	44	0.03881	–0.03836
White–fronted Bee–eater	83	0.0403	0.05214
Common Waxbill	140	0.04197	0.05446
Lesser Striped Swallow	101	0.04354	–0.02647

Long–tailed Widowbird	114	0.044	0.2503
Diderick Cuckoo	144	0.04524	–0.02192
Pearl–breasted Swallow	68	0.04626	–0.01838
Lesser Grey Shrike	81	0.04737	–0.03647
Yellow Canary	80	0.0482	–0.02647
Green–winged Pytilia	56	0.05003	–0.05407
Neddicky Neddicky	139	0.05081	0.07164
Northern Black Korhaan	101	0.0515	0.05968
White–faced Duck	133	0.05169	0.03189
Little Grebe	139	0.05184	0.03685
Chinspot Batis	90	0.05258	–0.00616
Barn Swallow	144	0.05272	0.0557
Zitting Cisticola	144	0.05309	0.05777
Red–backed Shrike	102	0.05313	–0.03631
Crested Francolin	57	0.05351	–0.04619
Desert Cisticola	115	0.0578	–0.01435
Red–billed Teal	121	0.0589	0.07524
Marico Sunbird	47	0.06097	–0.04726
Black–winged Stilt	93	0.06257	–0.00948
Yellow–crowned Bishop	134	0.06263	0.05186
African Quailfinch	117	0.06405	0.03813
White–browed Sparrow–Weaver	110	0.06464	0.18411
Namaqua Dove	87	0.06508	–0.03384
Three–banded Plover	137	0.06973	0.03018
Pin–tailed Whydah	143	0.0712	0.05726
Black–throated Canary	144	0.07164	0.04255
Southern Yellow–billed Hornbill	33	0.07525	–0.0805
Black–shouldered Kite	144	0.0768	0.08516
Crimson–breasted Shrike	78	0.07685	–0.05637
Lilac–breasted Roller	48	0.07691	–0.05851

Red–billed Quelea	142	0.07975	0.04547
White–winged Widowbird	128	0.07992	0.0217
Brown–crowned Tchagra	86	0.08212	–0.10008
Acacia Pied Barbet	91	0.09288	–0.08994
Red–breasted Swallow	74	0.09645	–0.06465
Chestnut–vented Tit–Babbler	99	0.10019	–0.03897
Magpie Shrike	45	0.10731	–0.09492
Sabota Lark	50	0.11287	–0.10228
Rufous–naped Lark	137	0.11454	0.08806
White–browed Scrub–Robin	66	0.11659	–0.09175
Marico Flycatcher	48	0.1219	–0.13497
Black–chested Prinia	144	0.12345	0.02506
Kalahari Scrub–Robin	66	0.12729	–0.10784
Long–billed Crombec	79	0.13163	–0.10042
Fork–tailed Drongo	80	0.13939	–0.08757
African Pipit	143	0.15248	0.08982
Scaly–feathered Finch	57	0.16365	–0.15156
Rattling Cisticola	80	0.16486	–0.13815
Blue Waxbill	88	0.18789	–0.11595

Table 7.2. Counts of numbers of species in eight sections of the number line in dimension 1 of Table 7.1

Section of number line	Number of species in section
x > 0.10	19
0.05 < x < 0.10	19
0.01 < x < 0.05	34
0.01 < x < 0	30
0 < x < –0.01	47
–0.01 < x < –0.05	70
–0.05 < x < –0.10	30
x < –0.10	14

Chapter 8

Conclusions

The primary purpose of this thesis was motivated by the question: “What conservation-relevant studies come out of the SABAP2 data from the four one-degree cells centred on Gauteng?” These four one-degree cells, referred to here as Greater Gauteng, contain the largest conurbation in South Africa, characterized by fast-paced development and exponential human population growth (Statistics South Africa, 2011). This area also has been the target of several highly successful SABAP2-driven challenges aimed at motivating citizen scientists to collect data for the bird atlas and to generate quality data to enable both real time and long-term monitoring of bird abundance and distribution in the region (Ainsley, 2016, Ainsley and Underhill, 2017). Underhill and Brooks (2016a) described the data-rich Greater Gauteng region as a “statistical heaven.” Tapping into the database from this “statistical heaven”, I have demonstrated in the chapters of this thesis, the range of possibilities that SABAP2 data can be applied to for the purposes of conservation of avian biodiversity.

One of the objectives of SABAP2 for Greater Gauteng project, as stated by Underhill and Brooks (2016a), is to show that with the large database generated by citizen science in the region, the Greater Gauteng can lead the world in turning atlasing (defined as finding the basic distributions of species) into spatial monitoring (establishing how distributions are changing through time). In this thesis, I have demonstrated that this objective is not only feasible, but already being achieved.

The results in the data chapters makes for two strong cases:

1. A case highlighting the fundamental importance of large volumes of data, and the useful information that can be harnessed from this data. Greater Gauteng as a region has generated the largest amount of SABAP2 data in South Africa (Ainsley). The conservation-relevant studies in the chapters of this thesis are a result of the spatial distribution patterns of the avifauna revealed by SABAP2 data from Greater Gauteng. It showed how we can detect changes in species abundance, richness and composition in a pentad or in any area, a method we can extend further to detect when bird species are starting to decline or drop out of the species list for a pentad.

2. A case for more data collection in other regions of South Africa following Greater Gauteng as a model. Greater Gauteng stands as a model region of rich and viable data (Ainsley, 2016). If other SABAP2 regions can generate as much or more data as this region, the conservation-relevant information that can mined from the data will be incredible. This will undoubtedly be a step in the right direction and will lead us closer to regional and global biodiversity monitoring and conservation goals. There is one published paper for an area of 75 pentads in the Western Cape that has produced comparable data; van Rooyen (2018) described a multi-year citizen science initiative that had, by 2018, generated adequate data for the methods of this thesis to be applied to this area.

Each chapter of this thesis addressed a question which resulted in a conservation-relevant study for the chapter. In summary, the thesis provides a new set of algorithms that can be used to assess the state of avian biodiversity and its spatial distribution. In this thesis, this was applied to the bird species of Greater Gauteng. It also reveals how urbanization is impacting the bird species richness and abundance in Greater

Gauteng. The results, contrary to my expectation on distribution of species abundance and richness in urban areas, show that the urban areas in Greater Gauteng holds more avifauna diversity; an indication that the urban areas of Greater Gauteng may be playing a more important role in the conservation of avian species than generally acknowledged as it still holds a significant pool of avian species richness and abundance.

Results also revealed the important ecological role played by IBAs in the region in the conservation of avifauna. Chapters Three and Four shows how different the Devon Grasslands and Suikerbosrand Nature Reserve IBAs respectively are markedly different in terms of birds' abundance, richness and diversity. The algorithm used in those chapters supports and gives quantitative credence to the BirdLife International criteria in designating these areas as IBAs. It can also be modified and used by conservation biologists to monitor the abundance and distribution of avifauna in the IBAs. An application that can be valuable for policy and management decisions (Cox et al., 2012).

Finally, I was able to develop a new application of the algorithm for a modified species diversity index (Harrison and Martinez, 1995, Underhill et al., 1998). This approach is estimated to 'capture' 97% of the species diversity in a pentad when there are 11 completed checklists, as was the case throughout Greater Gauteng. This algorithm is vastly preferable to making comparisons based on species richness (Harrison and Martinez, 1995). Harrison and Martinez, (1995) found that 93% and 96% of asymptotic value of the species diversity index in any given grid cell can be achieved with 5 and 10 checklists respectively. An ideal situation has been shown would be one which all grid cells in the study area has been sufficiently and equally sampled so that species diversity indices lay in the asymptotic portion of the curve. Greater Gauteng has been sufficiently sampled (Ainsley, 2016). All the pentads in Greater Gauteng have a minimum of 11 completed checklists, this gives an estimated 97% asymptotic value of the species diversity per pentad. This shows the results of this research captured 97% of more of the species diversity index in Greater Gauteng.

Plotted outcomes of the diversity of total and subgroups of species revealed the spatial distribution patterns of species and subgroup of species in the region, independently of the number of checklists submitted per pentad. It was also able to trace the spatial distribution of IBAs within Greater Gauteng. This algorithm is a powerful tool that can be applied along with ground-truthing in avian biodiversity monitoring and conservation as well as in identifying priority areas for avian species conservation.

Understanding the processes that underlie and influence observed patterns of species is a cardinal goal in ecological research (Harrison and Martinez, 1995, Austin, 2002, Brooks et al., 2004, Gibbons et al., 2007, van der Plas et al., 2017). Choosing the most appropriate data collection method and generating high quality data are crucial to gaining insights into these processes that define species distribution (Underhill et al., 1991, Duelli and Obtrist, 2003, Cox et al., 2012, Underhill and Brooks, 2016a, 2016b). The emergence of citizen science projects has resulted in the generation of large data on different species and on different temporal and spatial scales (Underhill and Brooks, 2016a). The value of high quality citizen science data cannot be over emphasized (Cox et al., 2012, Kosmala et al., 216). It is not only beneficial for biodiversity conservation goals, but is also to humans, when it demonstrates how the reconnection between people and nature boosts the health and well-being of the people and the environment (Devictor et al., 2010, Cox et al., 2017).

Over the years, conservation research has been intuitively focused on managing and protection of biodiversity in natural habitats more than the habitats in the urban environments (Edwards and Abivardi, 1998, Armsworth et al., 2004, Alvey, 2006, Kowarik, 2011). The concept that urban centres, characterised by human residential areas, have potential for biodiversity conservation is relatively new. It has not been extensively incorporated into research and species conservation efforts. Active management of the urban and suburban environments environment may contribute substantially towards the conservation of biodiversity in these environments (Cooper et al., 2007). This thesis supports this idea.

There is a strong correlation between a good management plan and high-quality data (Cabeza and Moilanen, 2001, Soberon and Peterson, 2004). A good management plan is a product of good policies which are reliant on sound research and monitoring based on high-quality data (Cabeza and Moilanen, 2001). This thesis highlights a number of factors crucial to a potential management plan for an urban ecosystem. It highlights the importance and efficiency of citizen science programmes like SABAP2 in efficiently conducting large-scale surveys of ecosystems and generating the high-quality bird data as used in this thesis. Such data is foundational to building a sound biodiversity management plan (Cabeza and Moilanen, 2001, Soberon and Peterson, 2004). The results discussed in the chapters of this thesis reveal the informative quality of the citizen science generated data as well as the potential of SABAP2 data to advance scientific knowledge which would otherwise be infeasible to generate using the traditional methods of generating data. Results show that urban ecosystem in Greater Gauteng still holds a remarkable proportion of avian diversity and is contributing perhaps more than we realize to biodiversity conservation in the region.

I hope that the outcome of this research will contribute to bridging of the knowledge gap in appreciating the contribution of urban ecosystems in avian biodiversity conservation especially as it concerns Greater Gauteng and ultimately Africa. I hope also that this research highlights the enormous potential of citizen science projects like SABAP2 to advance scientific knowledge, influence biodiversity conservation policy, and guide avian biodiversity management by producing datasets that would otherwise be infeasible to generate (Kosmala et al., 2016, Underhill and Brooks, 2016a, Underhill et al., 2017). With the overall goal being organizing citizens, research and habitat management activities towards achieving cumulative positive impacts on the conservation of avian biodiversity in urban areas (Cooper et al., 2007, Cox and Gaston, 2015).

A final but crucial 'take home' message from this thesis is an appreciation for the contribution that citizen science, atlasing and bird atlasers make to achievements in biodiversity conservation and statistical ecology. Without the contributions of thousands of citizen scientists, this thesis would not have been feasible. It is also worth noting here that though some scientists are often sceptical of the ability of citizen scientists to produce accurate datasets for scientific research, a growing body of publications is clearly showing that citizen-science projects is producing data with accuracy equal to or surpassing that of professionals (Cox et al., 2012, Kosmala et al., 2016). Successful citizen science projects rely on a suite of methods to boost data accuracy and account for bias, including volunteer training and testing, expert validation and replication across volunteers.

SABAP2 like other successful citizen science projects also employs methods through the SABAP2 protocol to ensure the quality of data generated by citizen scientists remains high and accurate (Ainsley, 2016, Underhill and Brooks, 2016). SABAP2 also organizes regular “atlas bashes” which entails a group of citizen scientists and professional scientists gather and atlas target pentads or areas together. This not only validates the data generated but also promotes even and uniform data is generated throughout the region. Furthermore, data generated by citizen scientists for SABAP2 goes through a vetting process by experts and experienced birders before it is uploaded to the SABAP2 database. All this goes to ensure the accuracy and quality of the SABAP2 data and the confidence with which the results of this thesis can be held.

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